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EFFECTS of the Arkansas River Multiple-Purpose Project on Agricultural Production

Volume I
Main Report

Prepared by
SOIL CONSERVATION SERVICE
in cooperation with
ECONOMIC RESEARCH SERVICE
FOREST SERVICE
and
AGRICULTURAL RESEARCH SERVICE
of the
U. S. DEPARTMENT OF AGRICULTURE

Little Rock, Arkansas
June 1970

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UNITED STATES DEPARTMENT OF AGRICULTURE

EFFECTS OF THE ARKANSAS RIVER MULTIPLE PURPOSE PROJECT ON AGRICULTURAL PRODUCTION

OKLAHOMA AND ARKANSAS

VOLUME INDEX

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UNITED STATES DEPARTMENT OF AGRICULTURE

EFFECTS OF THE ARKANSAS RIVER MULTIPLE-PURPOSE PROJECT ON AGRICULTURAL PRODUCTION

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EFFECTS OF THE ARKANSAS RIVER MULTIPLE-PURPOSE PROJECT ON AGRICULTURAL PRODUCTION

ABSTRACT

KEY WORDS: Arkansas River; agricultural production; Arkansas; Oklahoma; economic impacts; piezometers; tensiometers; water tables; watershed investigations; surface drainage; navigation; and projectional and observational studies.

ABSTRACT: The Arkansas River Multiple-Purpose Project (ARMPP) is scheduled to extend navigation from the Mississippi River to Catoosa Oklahoma in 1970. In addition, the project provides additional benefits of flood protection, hydroelectric power, and recreation.

This study was made to determine the effect of the Arkansas River Multiple-Purpose Project on agriculture. Observational, projectional, surface drainage, and economic impact studies and watershed investigations were made.

The observational study consisted of observing and keeping records of ARMPP effects on agricultural conditions, developments, use, and values within specified areas for representative combinations of the range of physical conditions of alluvial lands, farming, and ARMPP relationships for a period of years prior to and after ARMPP construction.

The projectional study consisted of analyzing available information and data from field reconnaissance and study and forecasting ARMPP related changes in physical conditions affecting agricultural use and values of certain areas. These effects were also evaluated as a basis for suggestions and recommendations to the Corps of Engineers for consideration of remedial measures and for guidance in USDA planning and programming.

The projectional study indicated that, for crops and forests in the estimated areas of changed water table, 75 percent would be benefited, 24 percent would be unchanged, and 1 percent would have damages. The observational study verified forecasts that damages did not generally occur where water tables were deeper than one foot and major crops were not benefited by water tables more than six feet deep.

Surface drainage problems caused by the navigation pools and flood waters on adjacent agricultural lands were studied. Additional investigations were made of the drainage problems in the entire basin. Reports of these drainage investigations were prepared for watersheds, by reaches, for the Arkansas portion.

The economic impact study consisted of analysis of the impact of ARMPP and all feasible upstream watershed projects on production of and return from major crops.

Installation of ARMPP resulted in a decrease of about 39,000 acres in cropland. The decrease in total value of annual crop production due to ARMPP amounted to about $953,000, or less than 1 percent.

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The adverse effects of ARMPP on production were concentrated in counties in which land was purchased for the Dardanelle and Robert S. Kerr structures. These counties are: Franklin, Johnson, Logan, Pope, and Yell Counties in Arkansas, and Haskell, Leflore, Muskogee, and Sequoyah in Oklahoma.

Raised water table benefits occurred in Arkansas, Conway, Desha, Jefferson, Lincoln, Lonoke, Pulaski, and Sebastian Counties in Arkansas, and Wagoner County in Oklahoma.

Most of the feasible upstream watershed projects are in the mainstem area south of Little Rock and in the Bayou Meto area. The counties affected are Arkansas, Jefferson, Lonoke, and Pulaski.

The ARMPP study area can still be expected to meet its historical share of U.S. food and fiber requirements in the future with current cropping patterns for all crops except wheat and soybeans. Requirements for these crops can be met by increases in production from changes in cropping patterns, use of cropland currently idle or in pasture, or from upstream projects.

Watershed investigations were made on all watersheds within the basin study area except those having recent detailed analysis, including 36 PL-566 projects, the Type IV river basin study on the Poteau River (1966), and the Bayou Meto Type IV river basin study now in progress. The watershed investigations were to determine the impact of ARMPP on all USDA programs, with particular reference to the feasibility of upstream watershed projects and associated changes in land use.

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INTRODUCTION

1. Why the study was made

This study was initiated by a request from the Corps of Engineers to the United States Department of Agriculture to determine the effects of the Arkansas River Multiple-Purpose Project (ARMPP) on agricultural lands. Determination of these effects was required for project evaluation and guidance in dealing with problems that might arise after construction. The study was also done to estimate the effect that ARMPP would have on the agricultural economy of the basin, including the possibilities for upstream watershed development. Finally, the study was made to determine methods of relating raised water surfaces to changes in groundwater tables.

2. Objectives of the study

The overall objective of this study was to evaluate the direct impact of ARMPP on agriculture in the Arkansas River Basin. Specific objectives were:

a. To analyze selected areas to predict the effects that will occur on crop and forest production under ARMPP operation. This is referred to as the projectional study.

b. To systematically observe and record changes actually occurring from preconstruction to postconstruction conditions as a result of ARMPP installation. This is referred to as the observational study.

c. To designate: (1) lands affected by impaired surface drainage through loss of surface drainage outlets; (2) lands subject to inundation or poor drainage; (3) and lands affected by changed groundwater table.

d. To evaluate the direct impact of navigation pools of ARMPP on agricultural production and income.

e. To evaluate the effect of ARMPP on the potential for development of upstream watershed projects.

3. Location of study area (Figures 1, 2, and 3. Pages 6, 12, and 25.)

The study area begins at the entrance of the Arkansas Post Navigation Canal at White River, mile 9.8 (1958 survey) in Arkansas and extends along the main stem of the Arkansas River to the Verdigris River, mile 460.2 (1940 survey), and the main stem of the Verdigris River to Head of Navigation, river mile 64.2 (1940 survey), in the vicinity of Catoosa, Oklahoma. The study area has been limited to about 14,707 square miles, the total drainage area below the peripheral dams. These dams and their respective drainage areas are:

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RESERVOIR PROJECT	DRAINAGE AREA (Sq. Miles)	RIVER BASIN	STATE
Oologah	4,339	Verdigris	Oklahoma
Keystone	74,506	Arkansas	"
Fort Gibson	12,492	Grand (Neosho)	"
Eufaula	47,522	Canadian	"
Tenkiller Ferry	1,610	Illinois	"
Wister	993	Poteau	"
Blue Mountain	488	Petit Jean	Arkansas
Nimrod	680	Fourche La Fave	"
Total -	142,630		

Drainage Area - Arkansas River Basin		160,645 Sq. Mi.
Drainage Area - Above Reservoir projects	1/141,637	
Areas excluded from Study Area:		
Ark. River - Keystone Dam to Verdigris River	1,345	
Hominy Creek	415	
Bird Creek (above Avant)	364	
Caney River (above Ramona)	1,955	
Dismal Swamp & Merisach Lake (diverted to White River)	82	
Dutch Creek (Trib. to Petit Jean Creek)	140	
Sub-Total		145,938 Sq. Mi.
Drainage Area of Study Area below dams and other exclusions (9,412,480 acres)		14,707 Sq. Mi.

1/ Excludes Wister Reservoir drainage area since entire Poteau River Basin is included in study area.

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Figure 1 shows location and Table 1 data pertaining to navigation and reservoir structures.

Table 1

Arkansas River Multiple-Purpose Project
Navigation Structures

Structure	Mile (1940 Survey Except as noted)	Elevations (Feet above m.s.l.) Upper pool	Lower pool	Lift (feet)	State
VERDIGRIS RIVER					
Head of Navigation	62.2-64.2	532.0			Oklahoma
Lock & Dam No. 18	35.5	532.0	511.0	21.0	Oklahoma
Dam No. 17	9.6	511.0	490.0		
Lock No. 17	8.5	511.0	490.0	21.0	Oklahoma
ARKANSAS RIVER					
Lock & Dam No. 16 1/ Webbers Falls	432.3	490.0	460.0	30.0	Oklahoma
Lock & Dam No. 15 1/ Robert S. Kerr	395.4	460.0	412.0	48.0	Oklahoma
Lock & Dam No. 14	375.1	412.0	392.0	20.0	Oklahoma
Lock & Dam No. 13	346.5	392.0	372.0	20.0	Arkansas
Lock & Dam No. 12 1/ Ozark	308.9	372.0	338.0	34.0	Arkansas
Lock & Dam No. 11	Deleted				
Lock & Dam No. 10 1/ Dardanelle	257.8	338.0	284.0	54.0	Arkansas
Lock & Dam No. 9	224.9	284.0-287.0	265.0	19.0	Arkansas
Lock & Dam No. 8	201.2	265.0	249.0	16.0	Arkansas
Lock & Dam No. 7	172.0	249.0	231.0	18.0	Arkansas
Lock & Dam No. 6 David D. Terry	154.4	231.0	213.0	18.0	Arkansas
Lock & Dam No. 5	128.0	213.0	196.0	17.0	Arkansas
Lock & Dam No. 4	2/ 87.7	196.0	182.0	14.0	Arkansas
Lock & Dam No. 3	2/ 72.3	182.0	162.0	20.0	Arkansas
Dam No. 2	2/ 40.5	162.0	Ark. River		
ARKANSAS POST CANAL					
Lock No. 2	3/ 13.4	162.0	142.0	20.0	Arkansas
Lock & Dam No. 1	3/ 10.4	142.0	112(White River)	30.0	Arkansas

1/ Multiple Purpose
2/ Mileage above mouth of Arkansas River based upon 1943 Survey to Lock and Dam No. 4
3/ Mileage above mouth of White River along Arkansas Post Canal

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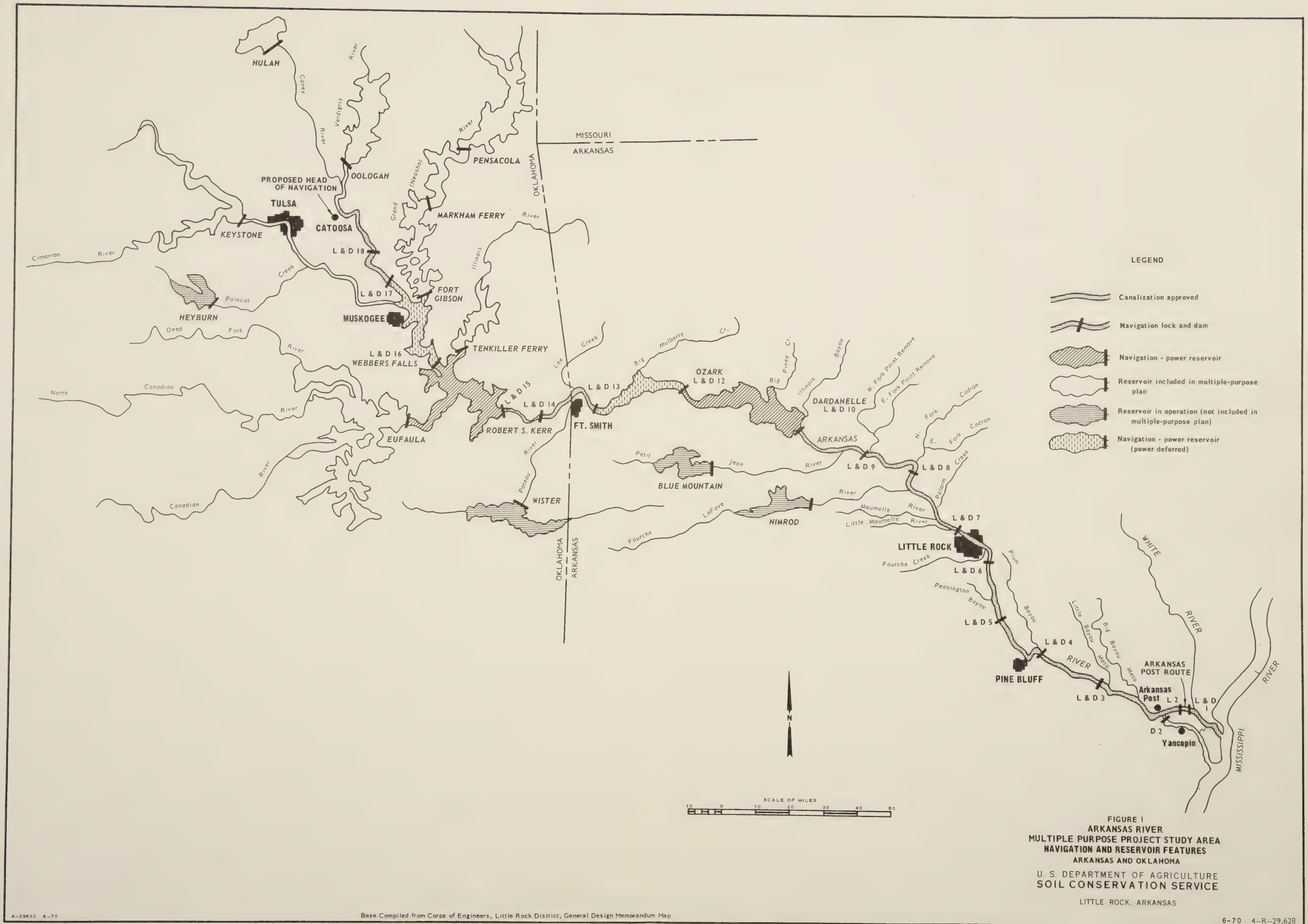

FIGURE 1
ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
NAVIGATION AND RESERVOIR FEATURES
ARKANSAS AND OKLAHOMA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

4. USDA agencies participating in study

The study of the ARMPP was made by the following USDA agencies: Agricultural Research Service, Economic Research Service, Forest Service, and Soil Conservation Service. Coordination of the work of these agencies was maintained by a Field Advisory Committee consisting of representatives from each agency. The Soil Conservation Service representative was chairman of the committee.

5. Authority for study

The USDA, under authority of Section 6, Public Law 566, 83rd Congress, agreed to participate in the study in response to the request of the Corps of Engineers.

6. Sponsoring agencies

The Corps of Engineers, Little Rock and Tulsa Districts funded the observational studies. The USDA funded the remainder of the study.

7. How study was made

The study was divided into five sections; Watershed Investigations, Surface Drainage, Observational Study, Projectional Study, and Economic Impacts. Each of these parts required a separate methodology as indicated below. Data developed in each section were used throughout the study where applicable.

Each part of the study was directed at the completion of one of the specific objectives of the study. However, the results from all parts of the study were necessary to accomplish the general objective of the study. The general methodology used in each part of the study is given in this part of the report. In the methodology section more detail on the interrelationships between the parts of the study is given.

a. Watershed investigations

The study area was divided into 135 watersheds or hydrologic units for evaluating the needs, apparent feasibility, and justification for watershed protection, flood prevention, agricultural and non-agricultural water management, recreation, fish and wildlife, and other purposes and determining the effects of the ARMPP on potential upstream projects.

b. Surface drainage

Investigations of surface drainage problems, including areal effects of the ARMPP were made by watersheds. All outlet structures affecting agricultural drainage were located, plotted on river hydraulic profiles, and classified with respect to size, number, elevations, and design capacities based generally on 5-year recurrence interval post-project river stages.

c. Observational study

The observational study was requested and funded by the Corps of Engineers on three areas selected by them by observing water table and piezometric surface and correlating these with plant response and river and pool stage

hydrographs. Shallow piezometers and tensiometers were installed in fields and observed each two weeks and other pertinent data were noted.

d. Projectional study

(1) Water table hydrographs were calculated from piezometric data. Some factors considered were piezometric hydrographs, water table depth, soil hydraulic conductivity, soil porosity, and the major factors of evapotranspiration and infiltration. The crops studied were small grain followed by soybeans (two-crop system), cotton, soybeans, alfalfa, and forest.

(2) Approximate methods were developed and used to predict crop responses to changes in water table. Reasonable estimates of plant respiration rate, growth rate, germination time, and anaerobic survival times were used in conjunction with estimates of soil and environmental characteristics to predict the effects of water tables on crop responses.

e. Economic impacts

A study of the overall economic impacts of the ARMPP was based on its effect on the productive capacity of agricultural soils. The change in gross value of production with constant cropping pattern was used as a "numeraire" of the change in productive capacity. Present and future conditions without and with the ARMPP project in place were estimated. However, cropping patterns by soil productivity group were held constant. The effect that the improved navigation channel might have on net returns to producers through reduced transportation rates was not considered. In addition, the effects on gross value of production of all feasible upstream watershed projects were estimated. This analysis was made to determine if the effects of the ARMPP could be counterbalanced by other kinds of development that may take place in the future even with the navigation project in place.

8. Use that can be made of report

The methods and procedures developed relating water tables to piezometric surfaces and plant responses to water tables for this study can be modified to fit similar projects on other river basins having similar problems.

Data from this study will be available to all agencies, groups, and organizations concerned with the planning and implementation of projects and programs in the field of water and related land resources.

9. Prior survey reports

a. ARMPP report (Corps of Engineers)

Arkansas River and Tributaries Report, Arkansas and Oklahoma, House Document Numbered 758, 79th Congress, relates to the multiple-purpose plan of development for the Arkansas River and tributaries as authorized by the River and Harbor Act of July 24, 1946. The plan was subsequently

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modified by congressional action and by progressive planning studies during construction of the navigation features.

b. AWRBIAC report

A comprehensive report, dated June 1955, on the conservation and development of the water and related land resources of the Arkansas-White-Red River Basins, was authorized in Section 205, Public Law 516, 81st Congress, 2nd session. The report was prepared by the Arkansas-White-Red River Interagency Committee, organized in 1950 by direction of the President to coordinate the work of the Federal agencies and the States.

c. ARMPP reports - Phase I study (USDA)

A report, Phase I, Survey of Agricultural Aspects of Arkansas River Multiple-Purpose Project, was prepared by USDA under authority of Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, 68 Stat. 666) as amended.

The Corps of Engineers requested the USDA to evaluate effects of ARMPP on agricultural lands and to assist in decisions relative to possible remedial measures.

Although full objectives of the Phase I study were not achieved, due to unavailable river post-project water surface profiles and projected groundwater maps of the ARMPP alluvial area, results of the Phase I study did establish a firm basis for the study described in this report.

d. Lower Mississippi River and Tributaries

Mississippi River and Tributaries project report was submitted in response to a Senate resolution adopted June 12, 1964 requesting a review of the project for flood control of the Mississippi River as published in House Document Numbered 359, 77th Congress, 1st Session, and other reports, as authorized by the Flood Control Act approved May 15, 1928, as amended by subsequent Acts of Congress.

In addition to the above listed resolution, the comprehensive review includes response to 16 other resolutions and 2 specific acts of Congress relating to the Mississippi River or certain tributaries in the alluvial valley.

10. Acknowledgements

Carl McGrew and Wilson Ferguson of the Arkansas State SCS Office and Fred Dries and Henry Otsuki of the Oklahoma State SCS Office were helpful in the formation of soil resource groups and estimating yields for major crops.

Area and district conservationists and soil scientists aided in estimating land use and affected areas.

Dr. Jan van Schilfgaarde, Associate Director, L. M. Glymph, Assistant Director, Soil and Water Conservation Research Division, Beltsville, Maryland; and Dr. Herman Bouwer, Research Agricultural Engineer, U. S. Water Conservation Laboratory, Agricultural Research Service, Tempe, Arizona contributed significantly to the procedure for the projectional study. Their assistance was greatly appreciated.

Dr. Joseph T. Wooley, Plant Physiologist, Soil and Water Conservation Branch, Agricultural Research Service stationed at University of Illinois aided materially in the development of the procedure used to estimate the response of crops to shallow water tables.

Ir. W. C. Visser, Director, and his staff at the Institute for Land and Water Management Research, Wageningen, The Netherlands, provided valuable analysis of some of the data, particularly with respect to beneficial effects of the water tables.

We are also grateful to Ralph Klawitter and John A. Putnam, Project Leaders, respectively, Southeast and Southern Forest Experiment Stations, U. S. Forest Service, for their review of the study design for estimating the crop response to a heightened water table.

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DESCRIPTION OF THE BASIN STUDY AREA

1. Location

The drainage area of the Arkansas River Basin is 160,645 square miles and occupies parts of the States of Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, and Arkansas. The study area comprises an area of about 14,707 square miles in Oklahoma and Arkansas, limited by the constraints described in paragraph 3 of the Introduction.

The major tributaries in the Arkansas River Multiple-Purpose Project study area are the Verdigris River, Grand (Neosho) River, Illinois River, and the Canadian River in Oklahoma; the Poteau River in Oklahoma and Arkansas; and the Petit Jean River, Fourche La Fave River, and Bayou Meto in Arkansas.

The portion of the White River included in this study lies in the southeastern part of the State of Arkansas in Desha and Arkansas Counties. The navigation route begins at the confluence of the White River and the Mississippi River about 591 miles above Head of Passes, Louisiana. It follows the White River in a generally northern direction to the Arkansas Post Canal, approximate river mile 9.8 (1958 White River Survey).

The Arkansas Post Canal extends generally west through Arkansas County to join the Arkansas River at Arkansas Post National Monument.

From Arkansas Post the study area follows the Arkansas River including all or parts of Arkansas, Desha, Lincoln, Jefferson, Lonoke, Prairie, Grant, Saline, Pulaski, White, Cleburn, Faulkner, Van Buren, Conway, Perry, Yell, Pope, Searcy, Newton, Johnson, Logan, Scott, Franklin, Madison, Washington, Crawford, Sebastian, and Polk Counties to the Oklahoma state line, at Ft. Smith, Arkansas.

From Fort Smith, the study area continues to follow the Arkansas River westward into Oklahoma to the mouth of the Verdigris River northeast of Muskogee and then northward along the Verdigris River including all or parts of Adair, Sequoyah, Leflore, Latimer, Haskell, Cherokee, Pittsburg, McIntosh, Muskogee, Wagoner, Tulsa, Rogers, Mayes, Washington, and Osage Counties. The navigation channel extends to Catoosa, Oklahoma. The ARMPP Study Area is shown on Figure 2.

2. Climate

The ARMPP study area lies within a modified continental type climate that includes exposure to all of the North American airmass types. However, with its proximity to the Gulf of Mexico, the summer season is marked by prolonged periods of warm and humid weather.

Approximate seasonal distribution of precipitation for spring, winter, fall, and summer is 33, 30, 23, and 14 percent, respectively. Summer rainfall is almost completely of the convective and airmass variety with the driest period occurring in the summer and early fall. The

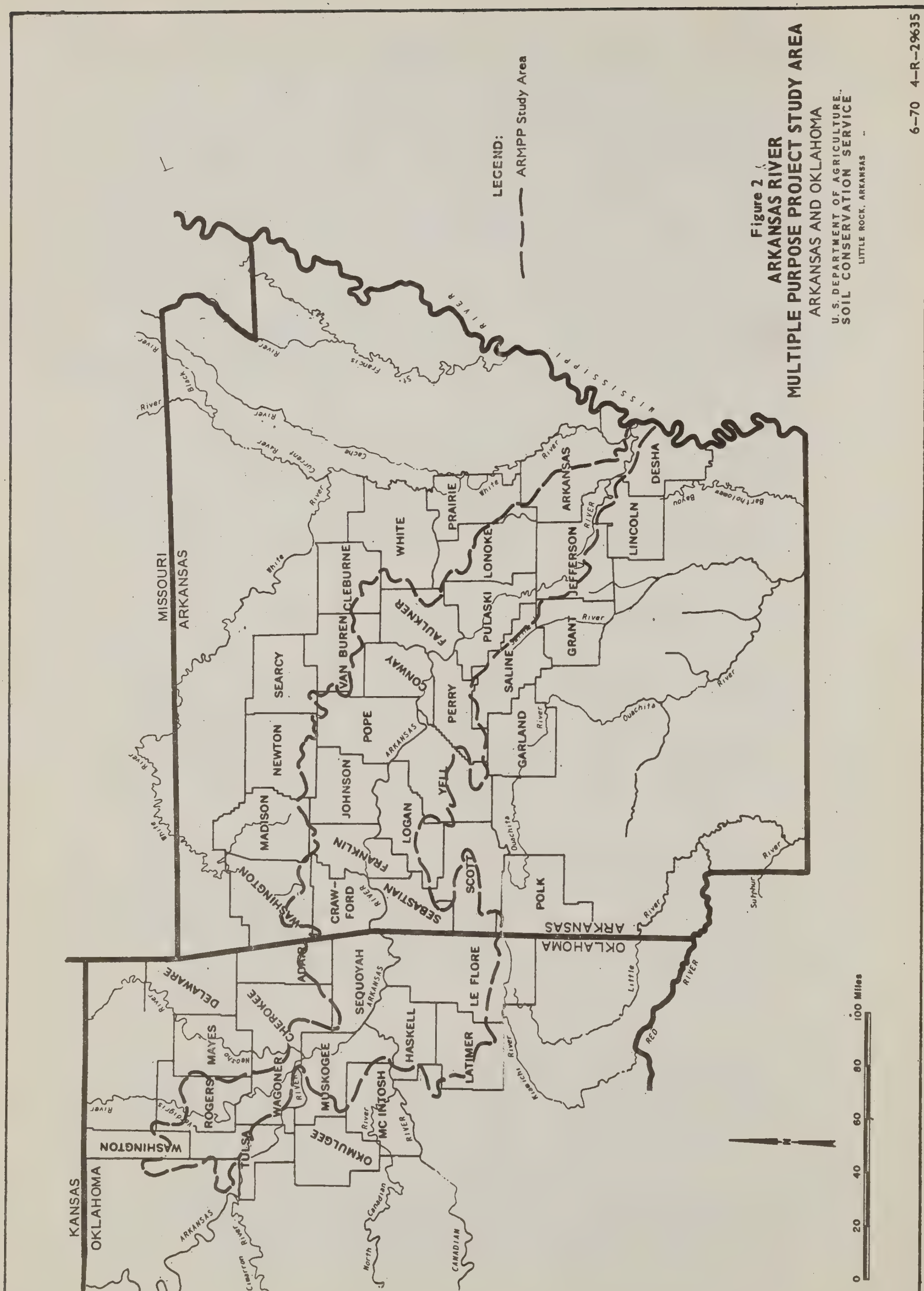

Figure 2
ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
ARKANSAS AND OKLAHOMA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

combination of active fronts and ample moisture in the winter and early spring months results in abundant rainfall amounts during this period.

Winters are mild, but polar and arctic outbreaks are not uncommon. The "Climatic Summary" (Table 2) shows U. S. Weather Bureau precipitation, temperature, and growing season records for selected locations in the Basin.

3. Physiography and geology

The part of the Arkansas River Basin studied in this report lies within three major physiographic provinces. These are the Coastal Plain, Interior Highlands, and the Central Lowland.

a. The Coastal Plain. This province comprises about 15 percent of the basin study area. Two major sections make up this province, the Mississippi Alluvial Plain and the West Gulf Coastal Plain. Elevations range from about 350 feet above mean sea level around Little Rock, Arkansas to about 150 feet above mean sea level at the mouth of the Arkansas River.

Near the western margin of this area rocks of Paleozoic Age crop out. These rocks dip steeply toward the Mississippi River where they are buried at depths of up to 5,000 feet. These sedimentary rocks are composed chiefly of well-indurated shale and sandstone.

The rocks of Paleozoic Age are overlain by rocks of Cretaceous Age. Sedimentary rocks of the Cretaceous Age do not crop out in the basin study area. However, a complex of intrusive igneous rock, believed to be of late Cretaceous Age, crop out in cupolas or stocks a few miles south of Little Rock.

Rocks of the Tertiary system include the Midway group (Paleocene), Wilcox group (Early Eocene), Claibourne group (Middle Eocene), and Jackson group (Late Eocene). These rocks dip and thicken to the southwest toward the Mississippi River.

The sedimentary rocks of the Tertiary system are overlain in much of the area by terrace deposits and alluvium of Quarternary Age.

There are many ox-bow lakes within the meander belt of the Arkansas River. A few of the largest are: Brushy Lake, Mud Lake, Jones Lake, Old River Lake, and Beaverskin Lake. Most of these lie north of the Arkansas River.

b. Interior Highland. Approximately 72 percent of the basin area is included within this province. This area extends from the longitude of Muskogee, Oklahoma to Little Rock, Arkansas. The Interior Highland within the basin study area may be subdivided into the Ozark Plateaus and the Ouachita Province.

The Ozark Plateaus are represented within the basin study area by the Boston "Mountain" area and to a much lesser extent by the Springfield Plateau. The Boston "Mountains" are found along the northern border of the study area in Arkansas and Oklahoma. About 14 percent of the basin

Table 2
CLIMATIC SUMMARY

LOCATION	PRECIPITATION (INCHES) Length of Record (Yrs.) 3/	Annual Highest 2/	Annual Lowest 2/	Aver. Annual 1/	Aver. Ann. Monthly Maximum 1/	Aver. Ann. Monthly Minimum 1/
Tulsa	82	62.8	23.2	38.4	5.02	1.62
Fort Smith	91	71.8	19.8	42.2	5.26	2.66
Dardanelle	83	76.6	28.9	48.6	5.50	2.96
Little Rock	91	75.5	28.3	48.7	5.28	2.82
Pine Bluff	84	82.9	34.7	52.1	5.36	2.42

LOCATION	TEMPERATURE (DEGREES FAHRENHEIT)						AVER. ANNUAL GROWING SEASON			
	Length of Record (Yrs.) 4/	Record High 4/	Record Low 3/	Aver. Annual 1/	Aver. Ann. Monthly Maximum 1/	Aver. Ann. Monthly Minimum 1/	Length of Record (Yrs.) 4/	First Mo. in Spring 4/	Last Mo. in Fall 4/	Growing Season (Days) 4/
Tulsa	34	115	-16	60.5	82.8	38.1	32	March	Nov.	221
Fort Smith	40	113	-15	61.8	83.0	39.8	40	"	"	234
Dardanelle	29	113	-11	62.7	82.6	42.2	29	"	"	220
Little Rock	40	110	-12	61.7	81.9	40.6	40	"	"	241
								"	"	
Pine Bluff	40	110	-6	64.5	83.1	45.1	40	"	"	228

1/ Based on the period 1931 to 1960 inclusive.
2/ Source: U.S. Weather Bureau, Little Rock office.
3/ Source: U.S. Weather Bureau Climatological Bulletins.
4/ Data obtained from 1941 Agricultural Year Book, Climate and Man.

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study area is located in this region. Most of the mountain tops stand at about the same level and form a greatly eroded table-land that rises 1,900 to 2,200 feet above mean sea level. Gorges 500 to 1,250 feet deep, which lie between steep ridges and jagged spurs, are common enough to warrant the application of the term "mountainous" to this highland region. Residual sandstone beds of Atoka Age cap this region. These beds are little folded. The southern slope from this region into the Arkansas Valley region of the Ouachita Province is gentle. However, in some areas, as north of Clarksville, Arkansas, the transition is abrupt.

The Ouachita Province may be divided into the Arkansas Valley and the Ouachita Mountains. There is a greater diversity in relief than in the Ozarks. The highest point is Magazine Mountain which has an elevation of 2,823 feet above mean sea level. All of the beds have underground crustal deformation and in some parts of the province have been intensely crumpled, folded, and thrust faulted.

The Arkansas Valley region ranges in width from 30 to 50 miles. It extends eastward from Muskogee, Oklahoma, to the Coastal Plain north of Little Rock. Approximately 43 percent of the basin area is in this region. The region is a gently undulating plain that generally stands between 300 to 600 feet above sea level. There are many long, sharp ridges that rise above this plain as well as several broad-topped synclinal mountains that trend in an eastwardly direction. The more prominent mountains are, Poteau, Petit Jean, Nebo, Magazine, Sugarloaf, and Cavanal.

The surface rocks consist of sandstone and shale of Carboniferous Age. Most of them belong to the Pennsylvania series. Structurally, this region is a synclinorium. The beds have been close folded and faulted near the southern part of the valley, but are more open folded near the Boston "Mountains."

The Arkansas River flows out of this region at about the latitude of Conway, Arkansas, into the Ouachita Mountain region.

The Ouachita Mountain region lies just south of the Arkansas Valley region. Approximately 15 percent of the basin area lies within this region. Unlike the Arkansas Valley, this region has been folded into an anticlinorium.

That part of this region within the basin area has been termed the "Frontal" Ouachitas. Parallel ridges are most characteristic of this region. In the western part the ridges are rugged and rise 1,000 feet or more above the adjacent stream valleys. The elevations decrease eastward until north of the Arkansas River they are barely 200 feet above the lowlands.

The rocks are all of Carboniferous Age and belong to the Stanley, Jackfork, and Atoka formations. They have been completely folded and thrust faulted. Many of the folds are recumbent.

Some of the more prominent mountains are Winding Stair, Rich, Fourche, Dutch Creek, and the Pinnacles just northwest of Little Rock.

c. The Central Lowland. This province occupies about 13 percent of the northwestern-most part of the basin study area. This province is a plain of low relief, generally less than 250 feet, interrupted at intervals by east-facing escarpments, which indicate the presence of stronger strata in a great mass of relatively weak rocks dipping gently westward toward the syncline of the Great Plains. This province has been subdivided into the Neosho Lowland, Claremore Cuesta Plains, and the Eastern Sandstone Cuesta Plain. Each of these have the same general characteristics as the province.

4. Land Resources

There are six major Land Resource Regions represented in the basin study area. These are: (1) Central Great Plains Winter Wheat and Range Region, (2) Southwestern Prairies Cotton and Forage Region, (3) Central Feed Grains and Livestock Region, (4) East and Central General Farming and Forest Region, (5) Mississippi Delta Cotton and Feed Grain Region, and (6) South Atlantic and Gulf Slope Cash Crop, Forest and Livestock Region. However, the data for the first two regions were incorporated with the Central Feed Grains and Livestock Region, since these two regions occupy less than 0.5 percent of the total study area and had a negligible effect on the land use. For the same reasons, data from the South Atlantic and Gulf Slope Cash Crop, Forest and Livestock Region were included in Mississippi Delta Cotton and Feed Grain Range. The land use of three major regions in the study area are given in Table 3, page 17.

a. Mississippi Delta Cotton and Feed Grain Region makes up 11 percent of the basin study area and lies principally within the Coastal Plain Physiographic Province. It is a level to a very gently rolling region. This predominately cultivated area is intensively managed for high value cash crops, principally cotton, soybeans, and rice. Irrigation, drainage, dikes, levees, and terraces are common land management practices. This seemingly endless cropped flat land is occasionally interrupted by small scattered farm woodlots. These woodlands occur on poorly drained soils, in swamps, and in bottomlands that flood frequently. Very little (5 percent) of the region is used for pasture and range.

b. East and Central General Farming Region comprises the central 2/3 of the basin study area and lies principally within the Interior Highland Physiographic Province. This is a rugged, mountainous region characterized by long, steep, stony slopes often interrupted by rock outcrops. Forests, which cover more than 1/2 the area, consist mostly of pine south of the Boston "Mountains" and upland hardwoods north of these "mountains". About 1/3 the area, usually the more rolling land, is used for pasture and range. Less than 10 percent of the region is cropland. Cultivated land is restricted to narrow alluvial valleys with a little on upland flats. Corn, feed grain, hay, fruits, and vegetables are locally important to the agricultural economy.

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Table 3

Land Use By Land Resource Regions
Arkansas River Multiple-Purpose Project Study Area

(In Percent)

Land Resource Region	Percent of Study Area	Cropland	Pasture & Range	Forest 1/	Other	Total
Central Feed Grain Lovestock Region	23	21	61	16	2	100
East and Central General Farming and Forest Region	66	8	31	58	3	100
Mississippi Delta Cotton and Feed Grain Region	11	61	5	31	3	100
Total Study Area	100	16	34	48	2	100

1| The 1967 Conservation Needs Inventory did not include land use of Federally owned lands.

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c. Central Feed Grain and Livestock Region occurs only in Oklahoma in the western and northwestern part of the basin and lies principally within the Central Lowland Physiographic Province. It comprises 23 percent of the basin study area. Ninety percent of this region is the Cherokee Prairies Land Resource Area.

Most of this region is either pasture or range land, and livestock production is the leading agricultural industry. The steep, rocky bluffs and ridges where the soils are shallow, rocky, and infertile, are generally forested. Cropland is confined to the bottomlands and gentle lower side slopes. Principal crops grown are winter wheat, soybeans, corn, grain sorghum, other feed grains, and hay.

The 10 Land Resource Areas occurring within the study area were subdivided into 32 soil resource groups. Each of these groups represents a combination of soils with similar productivity and management problems.

5. Economy

a. General

(1) Population Characteristics
In 1960 the population of the counties that approximate the ARMPP study area was about 1,240,000. By 1967, the population was estimated to be 1,400,000.

In 1960, 64 percent of the population was urban, 27 percent rural nonfarm and 9 percent rural farm. The Oklahoma portion of the study area was slightly more urbanized than the Arkansas portion.

(2) Major Types of Economic Activity
On the basis of earnings in 1962, manufacturing was the most important sector of the economy of the study area (21 percent of total earning). Scattered throughout the area are plants involved in such diverse activities as petroleum manufacturing, food processing, stone and gravel, cans, bicycles, electronic equipment, and wood and wood products. The many facets of wholesale and retail business accounted for 17 percent of earnings. Services (13 percent); civilian government (12 percent); transportation, communication, and public utilities (9 percent); agriculture (8 percent); mining (7 percent); and contract construction (6 percent) were other important sectors of the economy. The finance, insurance, and real estate sector and the Federal military sector accounted for the balance.

These activities are not spread evenly over the ARMPP study area. Mining is concentrated in the Oklahoma portion of the area and agriculture in the Arkansas area. In the future, agriculture and mining are projected to decrease, while service and civilian government are expected to increase.

(3) Employment
Total employment in the area was reported at about 426,000 in the 1962 County and City Data Book. Wholesale and retail trade accounted for

27 percent of employment. Manufacturing, slightly more than half durable goods, had 25 percent of employment. Transportation, communication, and other public utilities made up 11 percent of total employment, while agriculture and construction each had 10 percent. Education services represented seven percent. Public administration and finance, insurance, and real estate amounted to ten percent.

Total employment in the ARMPP area is expected to increase about 78 percent by the year 2000 (Table 4). Agriculture employment is expected to decrease by about two-thirds. Mining and transportation, communication, and public utilities are expected to show only slight increases in employment, thus losing significance in the general economy. Wholesale and retail trade, contract construction and manufacturing are expected to about maintain their relative importance. Finance, insurance, and real estate, government, and service are expected to become much more important sectors of the economy.

(4) Income

In 1960 the per capita family income in the study area was $4,451 compared to the U. S. Average of $5,660. The Arkansas portion averaged $3,952 and the Oklahoma portion $4,885. In Arkansas, the counties' median incomes ranged from a low of $2,168 in Scott to $4,935 in Pulaski. In Oklahoma, the range was from $1,919 in Adair County to $6,279 in Washington County. In 10 counties in Arkansas and 7 in Oklahoma, more than half of the families had median incomes of less than $3,000. Pulaski County, Arkansas and Tulsa and Washington Counties in Oklahoma are counties with more than 10 percent of the families reporting an income in excess of $10,000.

(5) Urban Centers and Their Influence

The ARMPP area has a high concentration of population in a few urban centers. Counties with the five largest cities contained about 64 percent of the area population. These cities are Tulsa and Muskogee in Oklahoma and Little Rock, Pine Bluff, and Fort Smith in Arkansas. Little Rock is the State Capital of Arkansas and Tulsa is the second largest city in Oklahoma. With so many people in the urban area, the rural areas are relatively sparsely settled.

(6) Transportation

The addition of navigation on the Arkansas River broadened the existing transportation system. The area is serviced by an almost complete interstate highway that parallels the Arkansas River from Little Rock west. Additionally, many state, federal, and county roads crisscross the area. Pine Bluff, Little Rock, Fort Smith, Muskogee, and Tulsa are serviced by one or more airlines.

b. Agricultural

(1) Major Crop Enterprises

Agriculture is still a significant sector of the economy of the area. Rice, cotton, and soybeans are major crops east of Little Rock, particularly in the Bayou Meto Sub-basin. Feed grains are still important in the area west of Little Rock and in Oklahoma. Around Fort Smith, there is a small concentration of vegetable and fruit production.

Table 4-Projected percentage change in employment from 1960 to 2000, ARMPP Study Area

Sector	Percent Change
Agriculture, forest, and fisheries	-66
Mining	3
Contract Construction	70
Manufacturing	86
Transportation, communication and public utility	11
Wholesale and retail trade	60
Finance, insurance, and real estate	128
Service	169
Government	156
Total employment	78

Source: Derived from Preliminary Report on Economic Projection for Select Geographic Areas, 1929-2020, United States Water Resources Council, March, 1968.

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(2) Major Livestock Enterprises

Approximately one million head of cattle and calves were on hand in the ARMPP area in 1967, about 2/3 in the Oklahoma portion. About six percent of these were milk cows spread evenly between the two state portions. Only small amounts of hogs and sheep were in the area. Broiler production was concentrated in the Arkansas counties between Little Rock and Fort Smith, where over 72,000,000 broilers were produced in 1967.

(3) Value and Volume of Farm Output

Total value of all farm products sold for the ARMPP study area amounted to about $316 million in 1964. About $251 million was in Arkansas and $65 million in Oklahoma. Of the $129 million worth of crops sold, $110 million came from the Arkansas portion. Field crops accounted for $118 million; forest and horticultural specialities, $5 million; vegetables, $3 million; and fruit and nuts, $3 million.

Livestock returns came to $187 million, with $46 million from Oklahoma and $141 million from Arkansas. Poultry sales from the Oklahoma portion accounted for $8 million; dairy products, $7 million; and livestock and livestock products other than dairy and poultry, $31 million. Arkansas receipts were $107 million, $14 million, and $20 million for these respective groups.

Major crops in the area include soybeans, rice, and cotton. About 14 million bushels of soybeans were produced in 1967 in the basin. About 62 percent of this was in the Bayou Meto area and 10 percent in Oklahoma. Virtually all of the 6 million cwt. of rice was produced in the Bayou Meto and the mainstem area south of Little Rock. For cotton, about 9 percent of the approximately 100,000 bales were produced in Oklahoma with almost all the rest in the Bayou Meto and the Arkansas mainstem south of Little Rock.

Of the approximate 14 million bushels of sorghum, about 93 percent was produced in Oklahoma. About 84 percent of 3.3 million bushels of wheat was produced in Oklahoma. Of the approximate one million bushels of corn and oats, most was in the Arkansas mainstem area or the Oklahoma area. About half of all hay production and almost 90 percent of the alfalfa was in the Oklahoma section.

(4) Farm Operator Level of Living

The level of living index given in the 1962 County and City Data Book measured farm operator level of living with 100 as average for the U.S. The state averages were 91 for Oklahoma and 64 for Arkansas. The ARMPP study area had an average index of 71 with 68 for the Arkansas portion and 74 for the Oklahoma portion. Only Arkansas County in Arkansas with an index of 112, and Rogers, Tulsa, and Washington Counties in Oklahoma with indices of 106, 110, and 106, respectively, exceeded the national average. Seven counties in Arkansas and 11 in Oklahoma were below the state averages.

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c. Forestry

(1) Extent and Nature of the Resource

The forest occupies approximately 54 percent of the study area. In general, it consists of the following types: pine, 27 percent; oak-pine, 9 percent; upland hardwoods, 48 percent; bottomland hardwoods, including cypress, 16 percent. Most of the bottomland hardwoods occur in the swamps of eastern Arkansas. Most of the pine occurs south of the Boston "Mountains" in the western part of Arkansas and in the adjacent southeastern part of Oklahoma (Table 5).

The general pattern of forest land ownership consists of: 68 percent, farmer; 19 percent, forest industry; 10 percent, National Forest; and 3 percent, other public lands. Characteristically, the most intensely managed lands are owned by industry or are in the National Forest. With few exceptions, little or no management occurs on other forest lands, including other public lands. This lack of management reflects the basic attitude of most landowners that the woods are in the way of progress and have a low priority for investments of time or money.

In each land resource area, man cleared the forests from the better sites and retained them on areas of relatively lower economic productivity, a condition generally due either to the lower productive capacity of the soil itself, or because the site is more difficult to manage, or both. This attitude of pushing back the forests to make room for man is continuing in the Mississippi delta and prairie transitional areas of the basin study area. However, in the upland areas where, in the past, man overestimated his land management ability and, as a result, degraded much of the land resource, abandoned farms are reverting to the native hardwood forest type or passing through a temporary pine stage. The net result of the clearing of bottomland areas and the reforestation of abandoned upland areas has been an almost imperceptible increase in the total forest acreage of the study area.

TABLE 5

Distribution and Trend of Forest Types by Land Resource Region

Land Resource Region	1/ Est. Area Forested	Forest Acreage trend/yr.	FOREST TYPES: Pine	Oak-Pine	Upland Hardwoods	Bottom-land Hardwoods
			- - Percent - -			
Central Feed Grain	19	-0.5	15	12	64	9
East & Central General Farming	58	+0.8	41	7	48	4
Mississippi Delta	39	-1.0	4	2	15	79
Basin Study Area	54	+0.00874	27	9	48	16

Trends based on 1959 (Arkansas) and 1966 (Oklahoma) Forest Survey Data

1/Includes federally-owned land.

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Hardwoods occupy 64 percent of the forest land in the study area, and account for 55 percent of the growing stock and 42 percent of the live sawtimber. This reduction in percentage of hardwood sawtimber reflects continual cutting of hardwood stands in excess of their growth, particularly in the larger sawtimber stands.

TABLE 6

Volume of Growing Stock and Sawtimber on Commercial Forest Land by Stand Size Class and by Softwood and Hardwood

	GROWING STOCK			SAWTIMBER		
Stand Size	Total	Softwood	Hardwood	Total	Softwood	Hardwood
	- Million Cu. Ft. -			- Million Bd. Ft. -		
Sawtimber	1721.2	975.7	745.5	6643.4	4335.9	2307.5
Pole Timber	1081.7	330.7	751.0	1750.7	748.8	1001.9
Sapling and Seedling	234.5	50.8	183.7	539.2	158.4	380.8
Non-Stocked	12.6	.8	11.8	34.4	1.2	33.2
ALL CLASSES	3050.0	1358.0	1692.0	8967.7	5244.3	3723.4

(2) Utilization

Kind, volume, and value of output of all forest products after primary processing exceeds 42 million dollars. Hardwoods amount to 52 percent of this output. About half of the total volume is sawlogs, 35 percent is pulpwood and fuelwood, with posts, pilings, poles, miscellaneous industrial wood, and logging residues accounting for the remaining 15 percent of the volume.

(3) Employment and Income in Primary Processing

Total employment in lumber and wood products industries was reported at 3,460 in the 1960 census. At the same time, paper and allied products reported employment of 3,045. This combined employment was 2.43 percent of the total work force. With the exception of woods labor and governmental forestry employees, these people worked in some 182 wood-producing or primary wood-using industries throughout the study area. The value of employment in primary forest-based industries amounted to nearly 26 million dollars in 1960.

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METHODOLOGY

Each of the five parts of the study: watershed investigation, surface drainage, observational study, projectional study, and economic impacts, required a separate methodology. However, in accomplishing the overall objective of the total study, the specific objectives of each part of the study were interrelated. The study of economic impact served as a focal point to bring together information from the other parts of the study.

The watershed investigations and surface drainage studies were made to determine the effect of ARMPP on existing and potential upstream watershed projects and surface drainage systems. Determination was made of the feasibility of potential upstream watershed projects under pre- and post-ARMPP conditions. Similar studies were made of existing and needed surface drainage systems.

The observational study was designed to determine the effects of project-induced alterations in river stages on three areas. The objective was to determine if there was a change of actual water table elevation in the areas, the magnitude of the change, and the effect that such changes would have on crop response. Also, the observational study provided background data on soils, cropping patterns, and other facets of farm organization that were important to the economic impacts study.

The projectional study devised procedures for developing water table hydrographs from piezometric data so that the effects of changed water tables on crop response could be estimated throughout the basin. Data obtained from the observational study, such as the relationship of actual and potential transpiration for selected crops, were used in and provided support for the projectional study.

The study of economic impacts drew information from the Watershed Investigation and Surface Drainage Reports on the extent of areas affected by potential upstream projects. The observational and projectional studies provided data on crop responses and their areal extent.

1. Watershed investigations

The study area was divided into 135 watersheds to evaluate potential upstream structural and watershed protection measures. These watersheds are shown on the project map, Figure 3. Appraisal was made of effects of the ARMPP on upstream watersheds, including location of affected areas, outlet considerations, feasibility estimates, and suggested remedial measures where appropriate.

Watershed investigation reports, based on field and office studies, were made to determine water and related land resource problems, needs and justification for watershed protection, flood prevention, agricultural and non-agricultural water management, recreation, fish and wildlife, and other purposes. Water storage in potential upstream impoundment-type structures was investigated for flood prevention, municipal and industrial, recreation, fish and wildlife, and various multiple-purpose combinations.

LEGEND

WATERSHED	ARMPP NO.	CNI NO.
Area Between Levees from Existing Mouth of Arkansas River to Lock and Dam No. 6	1	1-218
Honey Locust Bayou (White River)	2	2-52
Merrisach Lake (White River)	3	2-51
Little Post Bayou	4	1-217
Moore Bayou	5	1-216
Mill Bayou	6	1aa-1
Bayou Meto	7	1aa-3
Bayou Two Prairie	8	1aa-5
Lower Little Bayou Meto	9	1aa-2
Upper Little Bayou Meto	10	1aa-4
Waterloo Drainage District	11	1-215
Tucker Lake Levee and Drainage District	12	1-214
Beaver Dam Bayou	13	1-208
Plum Bayou	14	1-209
Ashley Bayou	15	1-209a
Upper Bayou Meto	16	1aa-6
Caney Bayou (Pine Bluff Arsenal)	17	1-213
Love Creek	18	1-212
Tar Camp Creek	19	1-211
Harris Bayou	20	1-210
Pennington Bayou	21	1-207
Fourche Bayou	22	1-206
Fourche Creek	23	1-205
North Little Rock City Drains	24	1-204
Little Maumelle River	25	1-202
White Oak Bayou	26	1-203
Palarm Creek (South Fork)	27	1-201
Palarm Creek (North Fork)	28	1-199
Maumelle River	29	1-200
Roland Drainage District (Mill Bayou)	30	1-198
Beaverdam Creek	31	1-197
Faulkner County Levee District No. 2	32	1-195
Tupelo Bayou	33	1-194
East Fork Cadron Creek	34	1y-2
Lower Cadron Creek	35	1y-1
North Fork Cadron Creek	36	1y-3
Upper North Fork Cadron Creek	37	1y-4
Ross Hollow	38	1-196
South Fourche La Fave River	39	1z-2
Mill Creek	40	1z-1
Taylor Creek	41	1-193
Perry County Levee District No. 1 (Ouachita Creek)	42	1-192
Conway County Levee District No. 8, Gap Creek	43	1-191
Lower Point Remove Creek	44	1-184
East Fork Point Remove Creek	45	1-186
West Fork Point Remove Creek	46	1-185
Conway County Levee District No. 1 & (Miller Bayou) No. 10	47	1-187
Portland Bottoms	48	1-190
Conway County Levee District No. 6	49	1-188
Conway County Levee and Drainage District No. 1 (Martin Lake)	50	1-183
Cypress Creek	51	1-189
Rose Creek	52	1x-3
Carden Bottom Drainage District No. 2	53	1x-2
Cedar Creek	54	1x-1
Dowdle Bend	55	1-182
Horsehead Branch (Kuhn Bayou)	56	1-181
Pope County Levee and Drainage District No. 2 (Old Galla Creek)	57	1-180
Lake Atkins	58	1-179
Galla Creek	59	1-178
Holla Bend National Wildlife Refuge	60	1-177
Petit Jean River	61	1x-4
Big and Little Chickalah Creeks	62	1x-5
Cedar-Piney-Spring Creeks	63	1x-6
Mill Creek	64	1-176
Holla Bend Drainage and Levee District No. 1	65	1-175
Whig Creek	66	1-174
McCoy Creek	67	1-173
Illinois Bayou	68	1-172
Hayes Creek	69	1-171
Delaware Creek	70	1-170
Shoal Creek	71	1-167
Cabin Creek	72	1-166
Big Piney Creek	73	1-168
Little Piney Creek	74	1-169
Horsehead and Spadra Creeks	75	1-164
Cane Creek	76	1-165
Hegwood-Lower Six Mile Creeks	77	1-162
Pilot (Six Mile Creek)	78	1-163
Smith and Moore Creeks	79	1-160
Pond Creek	80	1-161
Ozark-Highlands	81	1-159
Mill Creek	82	1-155
River Ridge	83	1-158
Mulberry River	84	1-157
Little Mulberry Creek (Vine Prairie Lake)	85	1-156
Little Clear Creek (Little Frog Bayou)	86	1-151
Mays Branch	87	1-150
Vache Grasse Creek	88	1-148
Onion-Big Creek	89	1-154
James Fork Creek (Oklahoma and Arkansas)	90	1w-10
Poteau River (Oklahoma and Arkansas)	91	1w-1
Black Fork Creek (Oklahoma and Arkansas)	92	1w-3
Heavener Lateral	93	1w-2
Combined Creeks (Oklahoma and Arkansas)	94	1w-8
Poteau Lateral	95	1w-7
Cache Creek	96	1-138
Spiro and Bonanza Laterals (Oklahoma and Arkansas)	97	1w-11
Mill Creek	98	1w-12
Massard Creek	99	1-146
Little Vache Grasse Creek	100	1-147
Fort Smith (Town Drains)	101	1-144
Flat Rock Creek	102	1-145
Mays Branch-Rose Lake	103	1-149
Clear Creek (Frog Bayou)	104	1-152
Jones Fork Creek	105	1-153
Lower Lee Creek (Arkansas and Oklahoma)	106	1-142
Upper Lee Creek	107	1-143
Little Lee Creek	108	1-141
Garrison Creek (Oklahoma and Arkansas)	109	1-140
Big Skin Bayou	110	1-139
Sallisaw Creek	111	1-136
Vian Creek	112	1-133
Lower Illinois River	113	1u-9*
Little Sans Bois Creek	114	1-134
Cache Creek Bottom	115	1-137
Sans Bois Creek	116	1-135
Brazil Creek	117	1w-9
Caston-Mountain Creeks	118	1w-6
Holston-Reichert-Conser Creek	119	1w-4
Fourche-Maline Creek	120	1w-5
Georges Fork Creek	121	1-132
Dirty Creek (Includes South Fork Route for Navigation to Eufaula)	122	1-131
Spaniard Creek	123	1-130
Coody Creek	124	1-127
Greenleaf Creek	125	1-129
Spring Manard Bayou	126	1-128
Flower Creek	127	1t-42*
Pecan Creek	128	1-126
Adams-Coal Creeks	129	1s-26
Bull Creek Laterals	130	1s-25
Dog Creek	131	1s-24
Lower Middle Verdigris River	132	1s-23*
Lower Caney River	133	1S2-12
Lower Bird Creek	134	1s3-3
Lower Canadian River	135	1v-59
Little Cypress Creek	28a	1-199a
Prairie-Shiloh Creek	68a	1-172a

*Part of CNI Watershed

LEGEND

- Drainage
- County Seats
- Reservoirs
- Reserve Boundaries
- County Lines
- State Lines
- Arkansas River Basin Project Boundary
- Watershed Boundaries
- Watertable Study Area Not Within Delineated Watershed Boundary
- Closure Structure
- Dam
- Lock and Dam

STUDY AREAS NOT WITHIN DELINEATED WATERSHEDS

- (A) Reach No. 2, 3, and 4 South of Arkansas River
- (B) Reach No. 2 North of Arkansas River
- (C) Lower Illinois River

VICINITY MAP

Figure 3
ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
SUB-WATERSHEDS
ARKANSAS AND OKLAHOMA

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

APPROX. SCALE
1:1,250,000

BASE COMPILED FROM ARMY MAP SERVICE QUADRANGLE MAPS AT SCALE OF 1:250,000

4-70 4-R-29,204
Rev. 4-70 4-R-23,398

The watershed investigation reports included at least the following items: purposes, watershed descriptions, problems and needs, physical potential for meeting needs, proposed works of improvement, local interest in project development, nature and estimate of costs of improvements, effects and economic feasibility of potential development, appropriate data tables, and maps.

Watershed investigation reports serve as a guide for priority selection and future planning authorizations for watersheds under Public Law 566 or similar projects. Detailed interrelationships are shown between individual watersheds and the ARMPP. These reports are used in conjunction with other river basin reports to summarize watershed needs, problems, potential works of improvement, effects, costs, and benefits by regions and states.

Watershed investigation reports are included in Appendix 1 for 70 upstream watersheds in Arkansas and 29 watersheds in Oklahoma. Seven of the reports in Oklahoma were made as part of a Type IV Poteau River Basin Comprehensive Study completed in 1966. Investigations and reports of the remaining 22 watersheds were made by an Oklahoma watershed planning party. Similar studies and reports of Arkansas watersheds were made by Arkansas Soil and Water Conservation Commission personnel for upland watersheds and by the Arkansas River Basins Planning Party for delta or flatland watersheds.

Studies of the remaining 31 watersheds in Arkansas and 5 watersheds in Oklahoma were made under authority of the Watershed Protection and Flood Prevention Act, Public Law 566, as amended.

The Forest Service investigated and prepared reports of present forest conditions for each watershed. Recommendations for implementing forestry practices which will increase infiltration, reduce erosion and sedimentation, and increased productivity of forest products were included.

Principal study aids were ARMPP lock and dam design memoranda, river charts, hydraulic profiles and design memoranda, survey data from prior drainage investigations, and soil and drainage reports. Other study aids are listed in Appendix 2 references.

All outlets affecting agricultural drainage were located and plotted on river hydraulic profiles and classified with respect to size, number, and post-project discharge capacity at normal navigation pool elevations.

Drainage design capacities for flatland areas were computed by the Cypress Creek formula, $Q = CM^{5/6}$, where

- Q = average runoff rate for the 24 hour period of greatest runoff for a storm event in cubic feet per second
- C = the appropriate subwatershed drainage coefficient
- M = drainage area in square miles

The Soil Conservation Service generally uses a drainage coefficient C value of 45 for watershed and large group drainage projects in flatland areas. The coefficient C selected depends upon degree of protection desired. Drainage capacities for moderately sloping hill areas were computed by the formula $Q = 80M^{.753}$.

2. Surface drainage

Investigations of surface drainage problems in areas adjacent to the Arkansas River, including areal effects of the ARMPP, were made by watersheds and by Arkansas River Reaches as listed in Table 32, page 207. Surface drainage reach reports were prepared and correlated with preliminary investigation reports for all reaches in Arkansas. Narrative reports were prepared for each watershed or hydrologic unit in the reach.

The 5-year frequency post-project flood elevations at the various drainage outlet locations were obtained for the Corps of Engineers' hydraulic profiles. These were generally the elevations used to determine areas of impaired or blocked drainage and to compute drainage outlet capacities. Allowances for anticipated sediment deposition were made in the upper reaches of Dardanelle, Ozark, and Kerr multiple-purpose reservoirs.

A sample hydraulic profile, Figure 4, is included for Reach No. 3. Complete profiles are included in Appendix 2. Sample sets of drainage structure capacity computations and profiles are shown in Figures 5 through 8. Similar data are maintained in reference files for all outlet structures.

Detailed studies were made by river reaches and by individual drainage outlets in the reaches. Objectives were to determine lands inundated or affected by impaired surface drainage due to ARMPP. Study aids included river charts, lock and dam design memoranda, hydraulic profiles and design memoranda, and other available topographic maps and drainage reports. Reach narrative reports include the following: description of reach location; narrative summary of surface drainage features related to ARMPP by significant individual streams or channels, and drainage problems not related to ARMPP; outlet locations, elevations, design capacities, and specific effects of ARMPP; range in elevations of the agricultural lands in the reach; description and topographic maps of areas inundated by ARMPP; Corps of Engineers land acquisition criteria; recommendations relative to suggested remedial measures, description of remedial or mitigation measures planned by the Corps of Engineers, including alternatives studied to correct adverse effects of ARMPP; and pre-project and post-project river flow elevations for various frequencies. The areas affected by ARMPP are shown in the watershed investigation reports.

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Reach reports were not considered necessary for the Oklahoma reaches since the magnitude and complexity of ARMPP effects on surface drainage were less in this area. Effects on surface drainage related to ARMPP for eight watersheds in Oklahoma are covered in the Phase I study. Only 27 percent of the total area affected by blocked or impaired drainage lies in Oklahoma and 72 percent of the latter area is associated with Robert S. Kerr Reservoir (Reach 15). Reach maps with delineation of affected areas identical to those included in Arkansas reach reports are included in Appendix 1 for Oklahoma reaches 14, 15, 16, 17, and 18. Much of the pertinent data included in reach reports was incorporated into the Oklahoma preliminary investigation reports.

(Text continued on Page 34)

DRAINAGE STRUCTURES						
NO.	TYPE	SIZE	INVERT ELEV. R.S.	INVERT ELEV. L.S.	CROWN	GATES
18	CMP	42"	201.0	202.0	204.5	Sluice
23	CMP	2-60"	177.0	178.0	182.0	Sluice

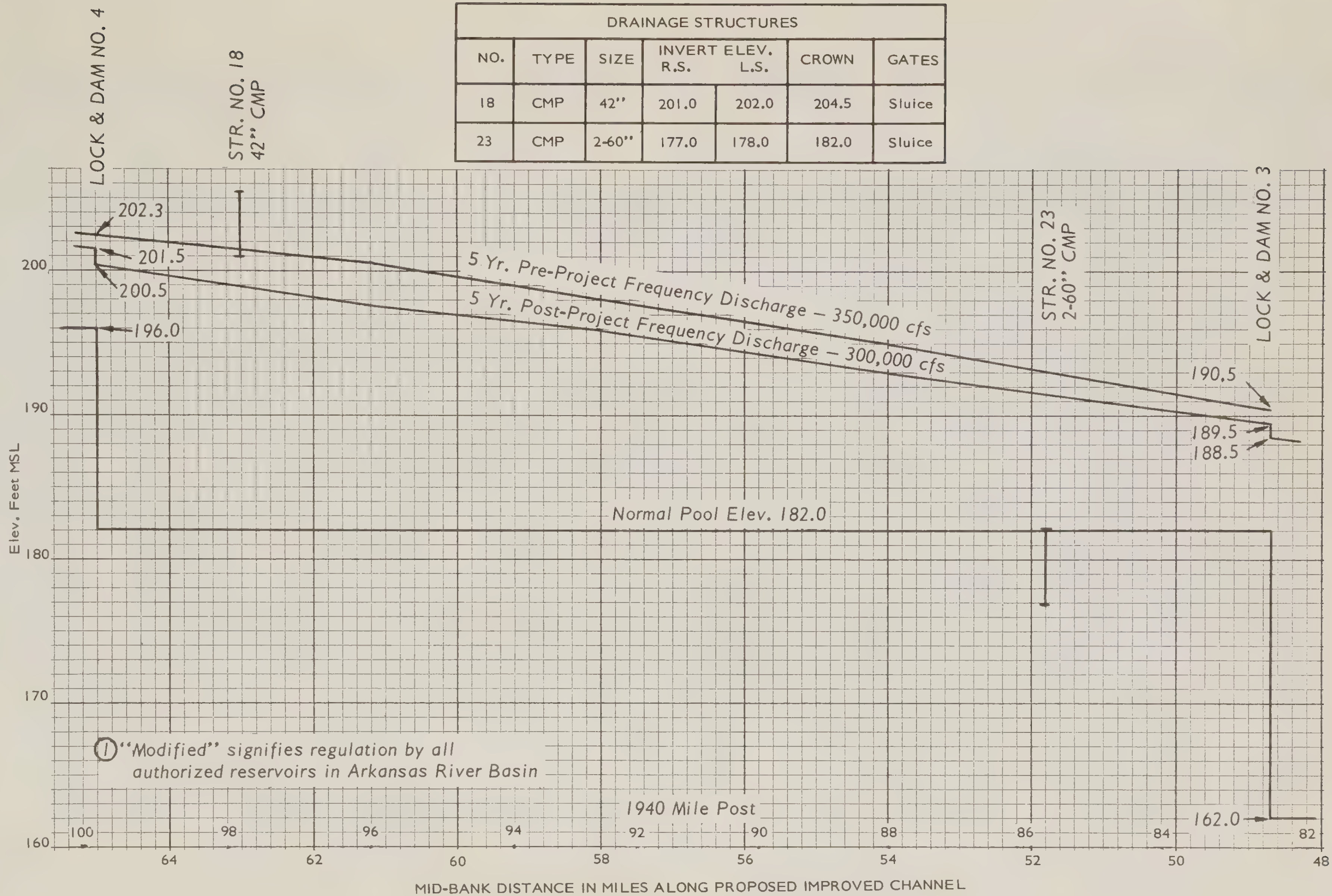

Figure 4

PROFILES AND DRAINAGE STRUCTURES-REACH NO. 3 (Sample)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LITTLE ROCK, ARKANSAS

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PROJECT: *Drainage Structure at Black Bayou*
Mile 9.4 on Plum Bayou
ARMPP – Reach No. 4

DESIGNER: *J. F. Burrow*

DATE ______

HYDROLOGIC AND CHANNEL INFORMATION

Q_1 = *637 cfs – 2 Boxes*

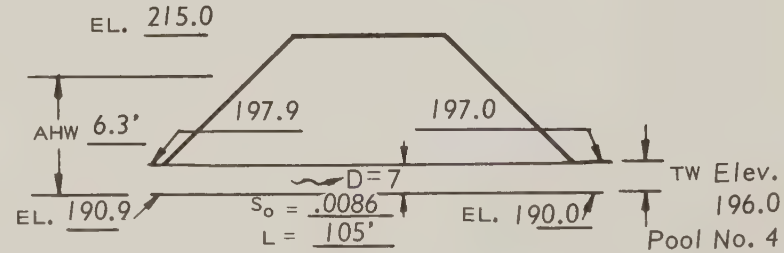
Q_2 = *318.5 cfs – 1 Box*

TW_1 = *6'* *Q/B = 318.5/7 = 45.5 cfs /ft.*

TW_2 = ______

SKETCH

STATION: *At Levee*



ALLOWABLE OUTLET VELOCITY = ______

CULVERT TYPE	Q	SIZE	HEADWATER COMPUTATION: INLET CONT. $\frac{HW}{D}$	INLET CONT. HW	OUTLET CONTROL K_e	d_c	$\frac{d_c + D}{2}$	h_o	H	LS_o	HW	CONTROLLING HW	OUTLET VELOCITY	COST	COMMENTS
2-7x7' RC Box	*318.5*	*1 Box 7x7'*	*0.9*	*6.30*	*0.5*	*4.0*	*5.5*	*6.0*	*1.1*	*0.9*	*6.2*	*6.3*			*Inlet Control*
with Sluice Gates															

SUMMARY AND RECOMMENDATIONS:

Figure 5

DRAINAGE OUTLET STRUCTURE DESIGN COMPUTATION (Sample)

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

LITTLE ROCK, ARKANSAS

DRAINAGE STRUCTURE AT BLACK BAYOU
2-7x7x105' RC Box
ARMPP Reach No. 4

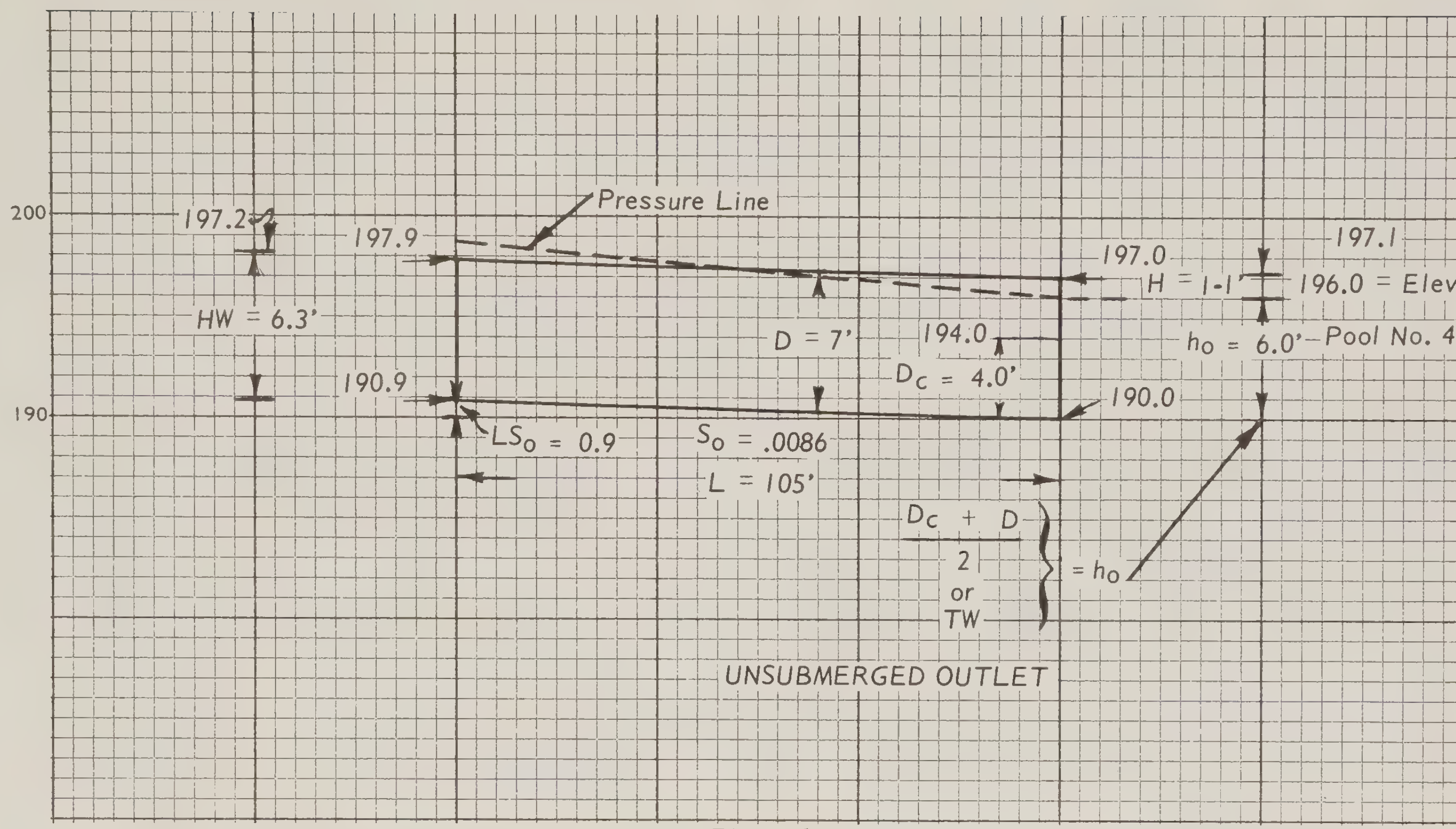


Figure 6

DRAINAGE OUTLET STRUCTURE DESIGN PROFILE (Sample)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LITTLE ROCK, ARKANSAS

PROJECT: *Flat Bayou*
Str. No. 10
Reach No. 4

REF: U.S. Department of Commerce
Bureau of Public Roads
Hydraulic Eng. Circular No. 5
Sept. 1961

DESIGNER: *J. F. Burrow*

DATE ______

HYDROLOGIC AND CHANNEL INFORMATION

Q_1 = *2,300 cfs Corps of Engrs. 10 Yr. Freq. 24 hrs. duration flood*

Q_2 = ______

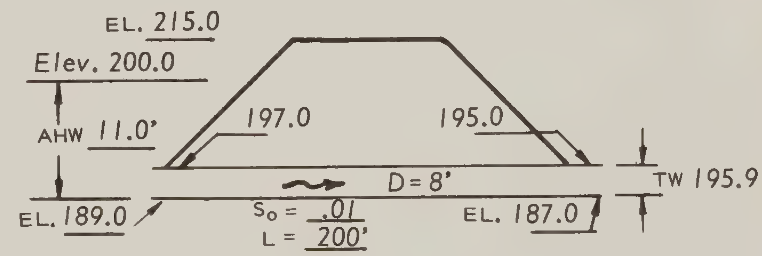
TW_1 = *8.9'*

TW_2 = ______

Q/B = 767/8 = 95.9 use 96.0 cfs/ft. } *1 Box*

SKETCH

STATION: *At Levee*



ALLOWABLE OUTLET VELOCITY = ______

CULVERT TYPE	Q	SIZE	HEADWATER COMPUTATION: INLET CONT. HW/D	INLET CONT. HW	OUTLET CONTROL K_e	d_c	$\frac{d_c + D}{2}$	h_o	H	LS_o	HW	CONTROLLING HW	OUTLET VELOCITY	COST	COMMENTS
3-8x8 RC Box	*767*	*1 Box 8x8'*	*1.38*	*11.04*	*0.5*	*6.6*	*7.3*	*8.9*	*4.1*	*2.0*	*11.0*	*11.0*			*Outlet Control*
with Sluice Gates															

SUMMARY AND RECOMMENDATIONS:

C = 0.73
A = 64 Sq. Ft.
P = 32'
r = 2'
h = 4.1'

$Q = CA\sqrt{2gh}$
$.73 \times 64 \sqrt{64.4 \times 4.1}$
$.73 \times 64 \sqrt{264.04}$
$.73 \times 64 \times 16.2$
$.73 \times 1036.8 = 756.9$ cfs
3 Boxes = $3 \times 756.9 = 2271$ cfs

Figure 7

DRAINAGE OUTLET STRUCTURE DESIGN COMPUTATIONS (Sample)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LITTLE ROCK, ARKANSAS

DRAINAGE STRUCTURE NO. 10
FLAT BAYOU – ARMPP
3-8x8x200' RCB WITH SLUICE GATES
REACH NO. 4

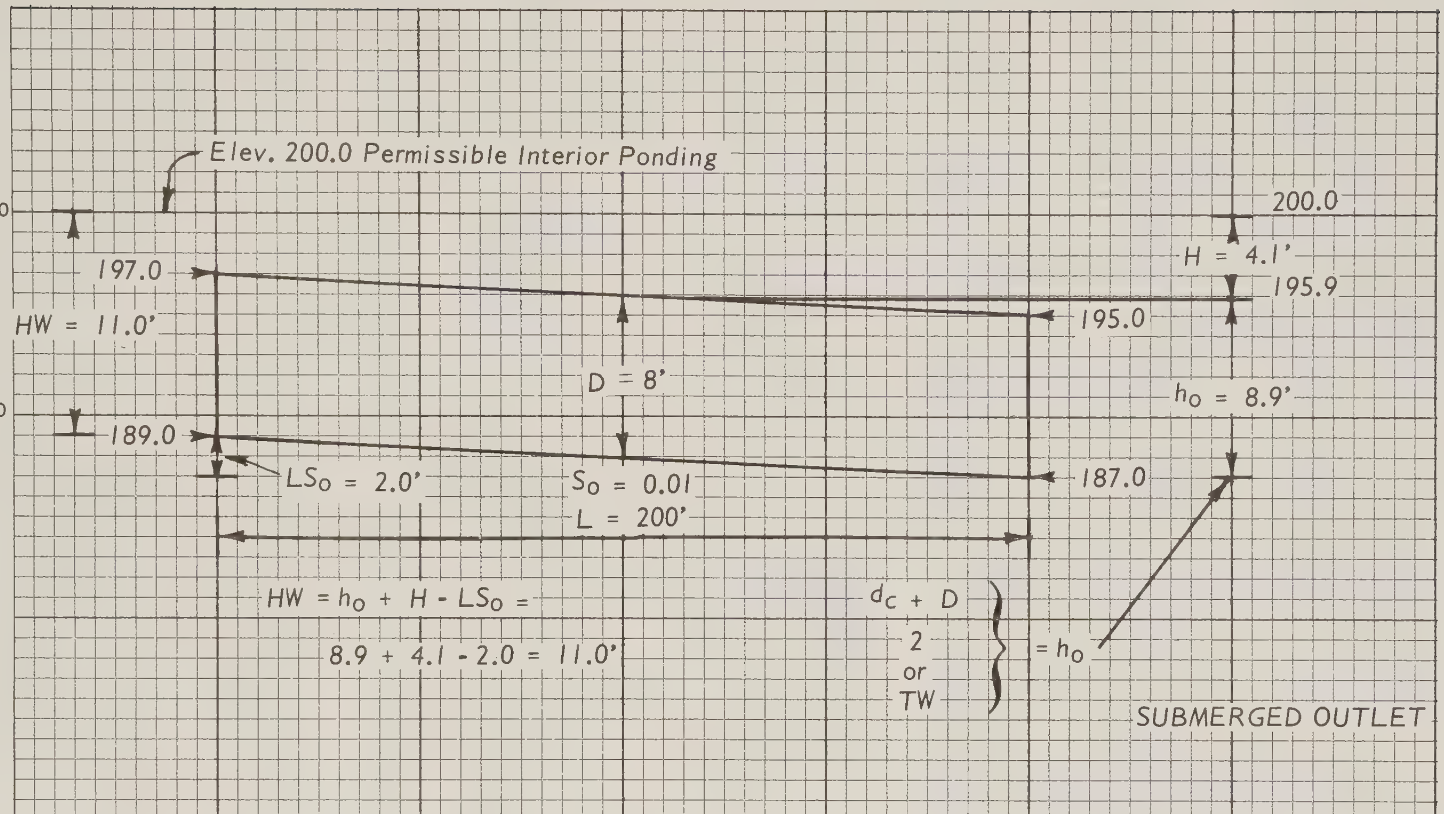


Figure 8

DRAINAGE OUTLET STRUCTURE DESIGN PROFILE (Sample)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LITTLE ROCK, ARKANSAS

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3. Observational study

The observational study was designed to determine what effects altered stream stages resulting from ARMPP would have on certain agricultural lands adjoining the Arkansas River. The objective was to determine if there was a change of actual water table elevation in the subject areas, the magnitude of the change, and the effect that such changes would have on crop response. The study was designed to make these determinations for both pre- and post-project conditions on different kinds of soils and for the major crops under varying degrees of groundwater fluctuations and depths. Areas where no water table occurred in the root zone were included.

Studies of this type and magnitude had never before been made; consequently, few procedures, guidelines or reliable reference data existed to aid in planning or carrying out of the study. Experience gained as the study progressed was helpful in ensuing years.

The observational study was started in 1963 on three areas in Arkansas: Fourche Island, on the right bank near Little Rock; Hartman Bottoms, on the left bank near Hartman; and McLean Bottoms, on the right bank near Paris.

These three areas were selected by the Corps of Engineers as being areas where there were possibilities of adverse effects accruing to agricultural lands from works of improvement included in the navigation project. These studies were funded by the Corps of Engineers. Available funds and resources limited the studies to the three areas.

Procedures -

Soils. Soils where observations were made were selected on the basis of their texture, subsurface permeability, distance from the river, and surface elevation. Site points representing the greatest possible range in these conditions were selected. Logs showing texture and color of the soils were made to 10-foot depths. There were 19, 22, and 19 observation points on Fourche Island, Hartman Bottoms, and McLean Bottoms, respectively.

Crops. Kind of crop was not usually a basis for selecting an observation point location, since crops may change annually; however, different crops were observed under similar conditions at several locations. Plant condition at time of observation was judged as excellent, very good, good, fair, or poor based on thickness of stand, color, insect damage, moisture stress, growth rate, set, size of plants, etc. Leaf area measurements were discontinued after the first part of the growing season because of the large changes that occurred between observation intervals (2 weeks). The degree of moisture stress in the plants was indicated as slight, moderate, heavy, growth retarding, and yield reducing. Insect activity was indicated as 0, 5, 15, or 30 percent of the leaf area eaten. Yield estimates were made on all mature crops, except alfalfa, by SCS personnel and farm operators. Any observable farm or land management practices that were carried out were noted.

Tensiometers. A 3-foot tensiometer was installed at each observation point to aid in differentiating between surface moisture and water table moisture effects and to provide information on the degree of drought. At 4 locations 1-foot and 2-foot tensiometers were also installed and at 2 of these locations 4-foot tensiometers were installed.

Piezometers. At each observation point 1 or more 3/8" inside diamter (I.D.) plastic tubing piezometers were installed at depths of from 5 to 10 feet. Readings were made of the deep USGS piezometers at the time of observation for correlation purposes. Water levels in the piezometers were measured using a "circuit breaker" at first; but later, a $\frac{1}{4}$" I. D. plastic bubble tube was used. It was operated by blowing in one end of the tube while lowering the other end into the piezometer until a bubbling noise was heard. The tubing was marked in 1/10 foot intervals.

Visual Records. Photographs were taken of the crops at each observation point at each visit from early growth of the plants until maximum growth. Only selected photos were taken during the remainder of the year. These photos have been filed and selected ones, characteristic of plant conditions, were shown in the Annual Reports.

Rain Gages. A network of "Tru Chek" wedge-shaped rain gages was installed on the observation areas. There were 17 gages on Fourche Island and 10 each on Hartman and McLean Bottoms. Reading of the rain gages was done by contract on Fourche Island and by local SCS employees on Hartman and McLean Bottoms.

Staff Gages and Flumes. Seven staff gages were installed to measure the stage and flows in the ditches of the PL-566 watershed project on Fourche Island. Two stage gages were installed on the Arkansas River; one at River Mile 159.4 off Fourche Island and the other on River Mile 297.4 between Hartman and McLean Bottoms. Some low-flow measurements were made on the PL-566 ditches on Fourche Island using Parshall flumes and V-type weirs.

Land Use. An annual inventory of kinds and acres of crops harvested was made on each of the three areas.

Production. Economic Observation Data - Sample yield and farm management data were obtained for the three observational areas. Additional data were gathered about the total-farm operations of the operators from which sample data were obtained.

Sample procedure - Data for land use and cropping patterns in the observation areas were mapped on aerial photographs and planimetered. All crops, pasture, and woodland for the observation areas were mapped and measured. Crop yields and management practices including planting dates, fertilization, cultivation, insect control, weed control, harvesting methods, and other farm management practices were based on sample survey data obtained from farm operators in the observation areas.

The sampling procedure was designed to estimate crop yields and management practices by soil units. An attempt was made to randomly select one field of each crop per soil unit within each square mile of an observation

area. Usually entire fields of each crop were included in the sample, but if the field was very large, the area was restricted to about 20 acres. All fields were included in which an observation point for groundwater and other physical characteristics was located.

It was assumed that, by selecting fields of crops at random throughout the areas, a representative sample of operators would also be included. In addition to crop yields and farm management data, total areas of crops and pasture, type and size of livestock enterprises, tenancy, and other information about total farm operations were obtained from each operator contacted. These data included their total-farm operations, both inside and outside the observation areas.

Experience in 1963 indicated that the procedures for making observational studies could be improved with the following slight modifications: Beginning in 1964 the soil was thoroughly compacted around the piezometers and tensiometers and the soil was left mounded around them to help prevent run in of surface water around them. Some observation points were moved short distances for various reasons such as surface water ponding, wilt spots in cotton, hot spots, and change in field boundary. Available moisture was determined at the surface of the soil and at the 6-inch depth at each observation date and was shown as 100+, 100, 75, 50, 25, or 0 percent where 100 percent is field capacity and 0 percent is wilting point.

During September 1964, soil samples were taken at the depth of each tensiometer sensor at each observation point for laboratory determination of percentage of soil moisture. Where undisturbed cores could be obtained, the percentage of soil moisture by volume was also determined. At the time of sampling an estimate was also made of the percentage of available soil moisture by feel and the estimate recorded. The following correlations were made and presented in the 1964 annual report.

1. Soil moisture content by weight vs soil moisture tension (centibars)
2. Soil moisture content by weight vs available soil moisture (percentage by weight)
3. Soil moisture content (percentage by volume) vs soil moisture tension (centibars)
4. Soil moisture content (percentage by volume) vs available soil moisture (percentage by weight)
5. Soil moisture tension (centibars) vs available soil moisture (percentage by weight)

In 1965 and subsequent years, the piezometers installed were polyethylene with a 5/8" I.D. and 13/16" O.D. These were installed in 15/16" diameter holes in the soil from 1 to 12 feet deep. Batteries of piezometers were installed at more observation points, usually with 1-foot difference in depth between the piezometers in the battery. On Fourche Island, nine of the rain gages were discontinued and one was added. On the other areas the rain gage network was unchanged.

Due to limitation of funds, information concerning farm organization, land use, crop production and management in the three study areas,

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analysis of data gathered, and preparation of appropriate summaries, conclusions, and reports concerning economic aspects was terminated in 1966.

In 1968 the observations on Upper Hartman Bottoms were discontinued because no water tables had been observed in that area. Eight observation points were added to the Lower Hartman Bottoms area where crops were being influenced by water tables.

After the analysis of 5 years of land use data on the observational areas, it appeared that the objectives of the land use inventory aspect of the study could not be obtained. Economic, weather, and other factors far overshadow the effect of water table changes on land use. Comparisons of land use changes in areas of water-table and no-water-table effects were poor, so land use inventories were discontinued in 1968.

More detail on the above procedures of how the observational study was made is included in the "Annual Reports, 1963, 1964, 1965, 1966, 1967, 1968, and 1969, Observational Study of Agricultural Aspects of the Arkansas River Multiple-Purpose Project." Current plans are for this study to be discontinued on Hartman and McLean Bottoms at the end of the 1970 crop year, and on Fourche Island at the end of crop year 1971, as requested by the Corps of Engineers.

4. Projectional study

a. Water table calculations

Two main problems encountered in the projectional study were: (1) continuous water table hydrographs were not available, and (2) data on the relationship between crop responses and fluctuating water tables were not available. Methods were devised to solve both of these problems. The following will explain how water table hydrographs were developed from periodic piezometric data; later the solution to the other problem will be explained.

Piezometric surface refers to the head in the underlying gravel and sand deposits, and water table refers to the phreatic surface in the fine-textured material overlying the gravel and sand.

The Agricultural Research Service, through Dr. Herman Bouwer, provided the following equation to calculate water table hydrographs from piezometric hydrographs:

$$\frac{h_2-h_1}{A-K} - \frac{2.3Kh_p}{(A-K)^2} \log \frac{(A-K)h_2+KH_p}{(A-K)h_1+Kh_p} = \frac{t_2-t_1}{f}$$, where

h_1 and h_2 = the water table heights above the base of the fine-textured material in feet at t_1 and t_2, which are time in days.

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A = accretion in feet per day. "A" is positive for a net excess of water, (percolation to the water table) and negative for a net loss of water from the water table (evaotranspiration).

K = hydraulic conductivity in feet per day.

h_p= piezometric pressure in the underlying sand and gravel or base of the fine-textured material.

f = fillable, or drainable, porosity for rising or falling water tables, respectively.

This equation describes the change in phreatic surface due to a change in piezometric head. The assumption was made that the effect of a change in the phreatic surface itself on the piezometric head is negligible. This assumption is valid if the gravel stratum is much more permeable than the fine-textured material. This is, of course, true, but for large distances from the river, storage or release of water due to a rising or falling phreatic level may have a measurable effect on the piezometric head.

The piezometric data available from the USGS consisted of records from a few recording piezometers, and a large number (about 2,000) of non-recording piezometers that were measured monthly or semi-annually. The piezometric data were interpolated to give continuous hydrographs from 1958 to 1962, inclusively. The location of the piezometers is shown in Figure 56, Pages 166-171 and Table 7 shows the piezometric data that were interpolated.

The monthly and semi-annual piezometer data were interpolated on the basis of recording piezometers, surrounding piezometers, and trends in fluctuation which extends in various directions and distances from the Arkansas River. Allowances were made for rapid drawdown and recovery of piezometric pressures at or near irrigation wells so they would be more representative of the larger surrounding area.

Post-project piezometric surface hydrographs were developed on the basis of the pre-project hydrographs, projected average piezometric surface (from the USGS), and pre- and post-project river and pool hydrographs.

The above described pre- and post-project hydrographs were used in the equation for the values of h_p at t_2.

The logs of the texture of the soils at the piezometer installations provided information on the hydraulic conductivity (K values) and elevations of the base of the fine-textured material at each piezometer. A sample areal map of these is shown in Figure 9. Four classes of hydraulic conductivity were used to categorize the soil texture as to permeability. The USGS data gave the permeability of the material as gallons per day per square foot which were converted to feet per day. The averages were grouped as follows:

(Text continued Page 75)

Table 7
(Sheet 1 of 36)
Analyses Made at Each Piezometer Location

	Pre-Project						Post-Project					
Piezometer Location	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
			1/									
T9S-R1W												
14ccc 2/		X	X2				X2					
16dbc		X	X2				X2					
17acc		X	X2				X2					
18cac		X	X2				X2					
27cbc		X	X2				X2					
T10S-R1W												
5cac	X2						X2					
9bba	X2						X2					
17aaa	X2						X2					
20bdc	X2						X2					
21daa	X2						X2					
23abb	X2						X2					
27acc	X2						X2					
28ccb	X2						X2					
31acb	X2						X2					
T11S-R1W												
30cba	X3						X3					
T6S-R2W												
28bbd		X	X1				X1					
32bbb		X	X1				X1					
33bab		X	X1				X1					
T7S-R2W												
4bbb		X	X1				X1					
5dda		X	X1				X1					
6acc		X	X1				X1					
7add		X	X1				X1					

1/ Numbers after X's
1. Not required because of depth.
2. <1.5' change in Piezometric Surface.
3. Post-Project Data unavailable.
4. Does not correlate with River stage.
5. C.E. purchase or easement.

2/ See Page 74

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Table 7
(Sheet 2 of 36)

Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Yes	Pre-Project: Water Table Hydrographs Calculated No	Yes	Pre-Project: Crop Affected By Water Table No	Yes	Post-Project: Piezometric Hydrograph Developed No	Yes	Post-Project: Water Table Hydrographs Calculated No	Yes	Post-Project: Crop Affected By Water Table No	Yes
T7S-R2W												
7caa		X	X1				X1					
7cca		X	X1				X1					
8cca		X	X1				X1					
8dcc		X	X1				X1					
17bba		X	X1				X1					
17cdc		X	X1				X1					
18cbc		X	X1				X1					
19ada		X	X1				X1					
20bab		X	X1				X1					
21bcb		X	X1				X1					
21dbc		X	X1				X1					
28abb		X	X1				X1					
30aaa		X	X1				X1					
31bbc		X	X1				X1					
32aaa		X	X1				X1					
32ddd		X	X1				X1					
33bca		X	X1				X1					
2425n		X	X1				X1					
2425s		X	X1				X1					
2425		X	X1				X1					
T9S-R2W												
1dbc		X	X2				X2					
4abd		X	X2				X2					
4add		X	X1				X1					
8abc		X	X2				X2					
10bbc		X	X2				X2					
10bbd		X	X2				X2					
10dab		X	X1				X1					
11bbc		X	X2				X2					
11cdd		X	X2				X2					
14cba		X	X2				X2					
14cdc		X	X2				X2					
23abc		X	X2				X2					
23dac		X	X2				X2					
24ccd		X	X2				X2					
26ddc		X	X2				X2					
27daa		X	X2				X2					
28dcc		X	X2				X2					
34abd		X	X2				X2					
35ccd		X	X2				X2					
35ddb		X	X2				X2					
36aac		X	X2				X2					

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Table 7
(Sheet 3 of 36)

Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Pre-Project: Piezometer Data Interpolated Yes	Pre-Project: Water Table Hydrographs Calculated No	Pre-Project: Water Table Hydrographs Calculated Yes	Pre-Project: Crop Affected By Water Table No	Pre-Project: Crop Affected By Water Table Yes	Post-Project: Piezometric Hydrograph Developed No	Post-Project: Piezometric Hydrograph Developed Yes	Post-Project: Water Table Hydrographs Calculated No	Post-Project: Water Table Hydrographs Calculated Yes	Post-Project: Crop Affected By Water Table No	Post-Project: Crop Affected By Water Table Yes
T10S-R2W												
4ccc	X2						X2					
6aab	X1						X1					
8bdd	X1						X1					
11ddc	X2						X2					
12daa	X2						X2					
14dcd	X1						X1					
18dbc	X1						X1					
20cbc	X1						X1					
21bca	X2						X2					
21dcb	X2						X2					
23cac	X1						X1					
24cca	X2						X2					
27ddd	X2						X2					
T11S-R2W												
3bca	X2						X2					
3daa	X1						X1					
3cca	X1						X1					
T12S-R2W												
1ddd	X1						X1					
13ada	X1						X1					
34ccc	X1						X1					
T6S-R3W												
7cbc		X	X1				X1					
8bcd		X	X1				X1					
8dda		X	X1				X1					
16aba		X	X1				X1					
16bbb		X	X1				X1					
17abb		X	X1				X1					
17ddc		X	X1				X1					
18cdc		X	X1				X1					
19add		X	X1				X1					
19dab		X	X1				X1					
20bac		X	X1				X1					
20cdd		X	X1				X1					
21acc		X	X1				X1					
21add		X	X1				X1					
21bab		X	X1				X1					
22bdc		X	X1				X1					
22daa		X	X1				X1					
27aaa		X	X1				X1					
28cbc		X	X1				X1					
28dcb		X	X1				X1					
28dcc		X	X1				X1					
29bcd		X	X1				X1					
30caa		X	X1				X1					

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Table 7
(Sheet 4 of 36)

	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T6S-R3W												
30dbb		X	X1				X1					
32aca		X	X1				X1					
32bcc		X	X1				X1					
32cbd		X	X1				X1					
32dda		X	X1				X1					
33ccb		X	X1				X1					
34acd		X	X1				X1					
T7S-R3W												
3adc		X	X1				X1					
4abb		X	X1				X1					
5bcd		X	X1				X1					
6cdc		X	X1				X1					
6daa		X	X1				X1					
6ddd		X	X1				X1					
7bda		X	X1				X1					
7ccd		X	X1				X1					
7dad		X	X1				X1					
8bca		X	X1				X1					
8bcc		X	X1				X1					
8cdb		X	X1				X1					
9bbb		X	X1				X1					
10abd		X	X1				X1					
15baa		X	X1				X1					
15ccc		X	X1				X1					
16baa		X	X1				X1					
17abc		X	X1				X1					
17dbb		X	X1				X1					
17ccb		X	X1				X1					
18aab		X	X1				X1					
18ccd		X	X1				X1					
19abd		X	X1				X1					
19ddd		X	X1				X1					
20acc		X	X1				X1					
20cdc		X	X1				X1					
21dac		X	X1				X1					
24aab		X	X1				X1					
24dcc		X	X1				X1					
25dcc		X	X1				X1					
29bbb		X	X1				X1					
29bda		X	X1				X1					
30acb		X	X1				X1					
30caa		X	X1				X1					
31aca		X	X1				X1					
32bbc		X	X1				X1					
2300c		X	X1				X1					

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Table 7
(Sheet 5 of 36)

Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Yes	Pre-Project: Water Table Hydrographs Calculated No	Yes	Pre-Project: Crop Affected By Water Table No	Yes	Post-Project: Piezometric Hydrograph Developed No	Yes	Post-Project: Water Table Hydrographs Calculated No	Yes	Post-Project: Crop Affected By Water Table No	Yes
T7S-R3W												
2300s		X	X1				X1					
2405		X	X1				X1					
2430		X	X1				X1					
T8S-R3W												
4cbc		X	X1				X1					
18cdb		X	X				X					
27acc		X		X	X			X		X		X
27ccc		X		X		X		X		X		X
29cdd		X		X		X		X		X		X
30aba		X		X		X		X		X		X
33abd		X		X		X		X		X		X
33ddc		X		X		X		X		X		X
2286		X		X	X		X					
2299	X1						X1					
2359	X1						X1					
T9S-R3W												
3cbb		X		X		X		X		X		X
4bab		X		X		X		X		X		X
7bbb		X		X		X		X		X		X
9aad		X		X		X		X		X		X
9cab		X		X		X		X		X		X
9dad		X		X		X		X		X		X
10abb		X		X		X		X		X		X
11cdd		X		X		X		X		X		X
14dac		X	X2				X2					
17dcb		X		X		X		X		X		X
20bdd		X		X		X		X		X		X
20cac		X		X		X		X		X		X
28abb		X	X2				X2					
29baa		X	X2				X2					
30aaa		X	X2				X2					
30acc		X		X	X		X2					
31adb		X	X2				X2					
31ddc		X	X2				X2					
35cca		X	X2				X2					
T10S-R3W												
4dad		X	X2				X2					
14aac		X	X2				X2					
15caa		X	X2				X2					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Pre-Project: Piezometer Data Interpolated Yes	Pre-Project: Water Table Hydrographs Calculated No	Pre-Project: Water Table Hydrographs Calculated Yes	Pre-Project: Crop Affected By Water Table No	Pre-Project: Crop Affected By Water Table Yes	Post-Project: Piezometric Hydrograph Developed No	Post-Project: Piezometric Hydrograph Developed Yes	Post-Project: Water Table Hydrographs Calculated No	Post-Project: Water Table Hydrographs Calculated Yes	Post-Project: Crop Affected By Water Table No	Post-Project: Crop Affected By Water Table Yes
T10S-R3W												
17dcc	X3						X3					
19dab	X3						X3					
20acd	X3						X3					
21dcb	X3						X3					
22cdc	X3						X3					
23dcc	X3						X3					
25cbb	X3						X3					
26ccb	X3						X3					
26dac	X3						X3					
27bbd	X3						X3					
27dbc	X3						X3					
28bbb	X3						X3					
30dbd	X3						X3					
31ccc	X3						X3					
35abb	X3						X3					
35ccc	X3						X3					
36bbb	X3						X3					
T5S-R4W												
19aaa		X	X1				X1					
19bab		X	X1				X1					
20cbc		X	X1				X1					
28dca		X	X1				X1					
29dad		X	X1				X1					
30aac		X	X1				X1					
T6S-R4W												
2aaa		X	X1				X1					
2baa		X	X1				X1					
3bba		X	X1				X1					
6bbb		X	X1				X1					
6ccc		X	X1				X1					
8dcd		X	X1				X1					
13acd		X	X1				X1					
17bcd		X	X1				X1					
18cbb		X	X1				X1					
23abc		X	X1				X1					
23ddc		X	X1				X1					
24abc		X	X1				X1					
24cab		X	X1				X1					
25acc		X	X1				X1					
26bac		X	X1				X1					
26cbc		X	X1				X1					
36aad		X	X1				X1					
36daa		X	X1				X1					

Piezometer Location	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T7S-R4W												
1aaa		X	X1				X1					
1abb		X	X1				X1					
1ddd		X	X1				X1					
2aaa		X	X1				X1					
2daa		X	X1				X1					
2ddd		X	X1				X1					
7aba		X	X1				X1					
11add		X	X1				X1					
11ddd		X	X1				X1					
12bcc		X	X1				X1					
12ddc	X4						X4					
13bda		X	X1				X1					
13dcc		X	X1				X1					
2293	X4						X4					
T8S-R4W												
3cad		X		X		X		X		X		X
7cda		X		X		X		X		X		X
8bbb		X		X		X		X		X		X
9bba		X		X		X		X		X		X
18dba		X		X		X		X		X		X
20ddc		X		X		X		X		X		X
32bcc		X		X		X		X		X		X
32dbb		X		X		X		X		X		X
34bcb		X		X	X			X		X		X
T9S-R4W												
2acd		X		X	X			X		X	X	
2bad		X		X	X			X		X	X	
5dad		X		X		X		X		X		X
6bbc		X		X		X		X		X		X
6daa		X		X		X		X		X		X
9acb		X		X		X		X		X		X
9cad		X		X	X			X		X		X
11ada		X		X		X		X		X		X
14bcc		X		X		X		X		X		X
16daa		X	X2				X2					
17bda		X		X		X		X		X		X
20bac		X	X1				X1					
21abb		X	X2				X2					
21dbb		X	X1				X1					
22dcd		X	X1				X1					
23acc		X		X	X			X		X		X
25acd		X		X	X			X		X		X
26bcc		X	X1				X1					
28cbb		X	X1				X1					
30baa		X	X1				X1					
34cbc		X	X1				X1					
36aac		X	X1				X1					

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Piezometer Location	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T10S-R4W												
2bab	X3						X3					
2bba	X3						X3					
2bba	X3						X3					
7bda	X3						X3					
13ccc	X3						X3					
23bac	X3						X3					
24dcb	X3						X3					
27cab	X3						X3					
27dac	X3						X3					
33acc	X3						X3					
T5S-R5W												
8cdb		X	X1				X1					
11cdd		X	X1				X1					
12ddc		X	X1				X1					
13dda		X	X1				X1					
15adc		X	X1				X1					
17cba		X	X1				X1					
21acd		X	X1				X1					
23dbb		X	X1				X1					
26cba		X	X1				X1					
35cda		X	X1				X1					
36aaa		X	X1				X1					
T6S-R5W												
1bcc	X4						X4					
3dbb		X	X1				X1					
6cda	X4						X4					
9ddd		X	X1				X1					
10abb		X	X1				X1					
12dab		X	X1				X1					
15bac		X	X1				X1					
15bca		X	X2				X2					
15bcb		X	X2				X2					
16dbc		X	X1				X1					
17dcc		X	X2				X2					
18adb		X	X2				X2					
21bcb		X	X2				X2					
21cab		X	X2				X2					
21cbb		X	X2				X2					
29aab		X	X2				X2					
29dca		X	X2				X2					
32cda		X	X1				X1					
34dad		X	X2				X2					

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	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T7S-R5W												
4aaa		X	X1				X1					
5ccc		X	X1				X1					
6acc		X	X1				X1					
6acc		X	X1				X1					
17ccc		X	X1				X1					
19bbb		X	X2				X2					
29ddd		X	X2				X2					
30aac		X	X2				X2					
33bdc		X	X2				X2					
T8S-R5W												
1adc		X		X		X		X		X		X
4adc		X	X2				X2					
8bda		X	X1				X1					
9cba		X		X		X		X		X		X
10bcb		X		X		X		X		X		X
12abd		X		X		X		X		X		X
13aad		X		X		X		X		X		X
25dab		X		X	X			X		X		X
27ccc		X		X		X		X		X		X
29acc		X	X1				X1					
34cac		X		X		X		X		X		X
T9S-R5W												
4aad		X		X	X			X		X		X
13cdb		X	X1				X1					
14abc		X		X	X			X		X		X
16bdc		X		X	X			X		X		X
17bcb		X		X	X			X		X		X
24abd	X3						X3					
25bac	X3						X3					
34bba	X3						X3					
T5S-R6W												
31caa		X		X		X		X		X		X
32bdc		X		X		X		X		X		X
33cbd		X		X		X		X		X		X
T6S-R6W												
4ada		X		X		X		X		X		X
9acc		X		X		X		X		X		X
11cca		X		X		X		X		X		X

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Piezometer Location	Pre-Project: Piezometer Data Interpolated		Pre-Project: Water Table Hydrographs Calculated		Pre-Project: Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Post-Project: Water Table Hydrographs Calculated		Post-Project: Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T6S-R6W												
13dab		X	X2				X2					
14ddc		X	X2				X2					
15dbb		X	X2				X2					
17dca		X		X		X		X		X		X
18acd		X		X	X			X		X		X
18daa		X		X	X			X		X		X
23aad		X	X2				X2					
23abb		X	X2				X2					
23aca		X	X2				X2					
T7S-R6W												
5bab		X		X	X			X		X		X
14aba		X	X1				X1					
15aba		X	X1				X1					
18caa		X	X1				X1					
21abc		X		X		X		X		X		X
24caa		X	X2				X2					
26bdd		X	X2				X2					
28cbb		X	X1				X1					
35bbb		X	X1				X1					
35cca		X	X1				X1					
T8S-R6W												
1cca		X	X1				X1					
2acb		X	X1				X1					
6aaa		X	X1				X1					
9bbc		X	X1				X1					
10bbb		X	X1				X1					
11bcc		X	X1				X1					
17add		X		X	X			X		X	X	
19ddb		X	X1				X1					
21bbc		X		X	X			X		X	X	
28cca		X		X	X			X		X	X	
28cdc		X		X	X			X		X	X	
29bbb		X	X1				X1					
31dbc		X	X1				X1					
T9S-R6W												
3abb		X		X	X			X		X	X	
3bad		X	X1				X1					
3cba		X		X		X		X		X		X
T2S-R7W												
18bbb	X3											

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	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T3S-R7W												
32bbd	X3											
33cdc	X3											
T4S-R7W												
4bdc	X3											
6cab		X		X	X			X		X	X	
18bcc		X	X1				X1					
19bca		X		X	X			X		X	X	
20dbc		X	X1				X1					
21dba		X	X1				X1					
29caa		X		X	X			X		X	X	
29dbb		X		X	X			X		X	X	
31ccb		X		X	X			X		X		X
32bdb		X		X	X			X		X		X
35dda		X		X	X			X		X		X
T5S-R7W												
1dab		X		X	X			X		X		X
5aaa		X		X	X			X		X		X
5bbb		X		X	X			X		X		X
5ddb		X		X	X			X		X		X
6bbd		X		X	X			X		X		X
6bcb		X		X	X			X		X		X
7bbb		X		X	X			X		X		X
7cbc		X		X	X			X		X		X
18bbb		X		X		X		X		X		X
18cbb		X		X	X			X		X		X
19bcc		X		X	X			X		X	X	
19cbc		X	X1				X1					
25bca		X		X		X		X		X		X
27cca		X		X	X			X		X		X
27cda		X		X	X			X		X		X
27cdb		X		X	X			X		X		X
27cdc		X		X	X			X		X	X	
30bbb		X		X	X			X		X	X	
33bdc		X		X	X			X		X	X	
35abb		X		X		X		X		X		X
35bcd		X		X	X			X		X		X
35cdd		X		X	X			X		X		X
36bcc		X		X		X		X		X		X
T6S-R7W												
2caa		X		X	X			X		X	X	
4bab		X	X1				X1					
6bba		X	X1				X1					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated		Pre-Project: Water Table Hydrographs Calculated		Pre-Project: Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Post-Project: Water Table Hydrographs Calculated		Post-Project: Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T6S-R7W												
13baa		X		X	X			X		X		X
17cca		X	X1				X1					
18abb		X	X1				X1					
18add		X	X1				X1					
19abc		X	X1				X1					
19dcb		X	X1				X1					
30abb		X	X1				X1					
30acc		X	X1				X1					
30cad		X	X1				X1					
30ccc		X	X1				X1					
31aca		X		X	X			X		X	X	
32ccc		X		X	X			X		X		X
T7S-R7W												
8bba		X		X	X			X		X		X
16abb		X		X	X			X		X	X	
16adc		X		X	X			X		X	X	
16bbd		X		X	X			X		X	X	
16cac		X		X	X			X		X	X	
16ccd		X		X	X			X		X	X	
18ada		X		X	X			X		X		X
19aaa		X		X	X			X		X		X
21dbc		X		X	X			X		X		X
22cbc		X		X	X			X		X		X
22dbb		X		X	X			X		X		X
25bac		X		X	X			X		X	X	
26dcb		X		X	X			X		X		X
28abb		X		X	X			X		X		X
29bca		X		X	X			X		X		X
29ddd		X		X		X		X		X		X
30ccd		X	X1				X1					
31abd		X		X		X		X		X		X
T8S-R7W												
8dac		X		X	X			X		X		X
9bbd		X	X1				X1					
11aca		X	X1				X1					
17add		X		X		X		X		X		X
21bbb		X	X1				X1					
21cbb		X	X1				X1					
22acd		X	X1				X1					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T9S-R7W												
1cbb	X4						X4					
2dbb	X4						X4					
3dad	X4						X4					
T1S-R8W												
22cbb	X1						X1					
T3S-R8W												
14ada	X1						X1					
15add	X1						X1					
15bdc	X1						X1					
24ccc	X1						X1					
24dda	X1						X1					
35aab	X1						X1					
T4S-R8W												
25caa		X		X	X			X		X	X	
T5S-R8W												
1ccb	X4						X4					
12bba		X	X1				X1					
12daa		X		X	X			X		X		X
35ddd		X		X	X			X		X	X	
36aad		X		X	X			X		X		X
T6S-R8W												
10acd		X	X1				X1					
10dcd		X	X1				X1					
10ddc		X	X1				X1					
11cbb		X	X1				X1					
14abc		X	X1				X1					
21acb	X4						X4					
22ada		X		X	X			X		X		X
23bcc		X		X	X			X		X		X
23cba		X		X	X			X		X		X
24aab		X	X1				X1					
24cdc		X	X1				X1					
24dcc		X	X1				X1					
25abb		X	X1				X1					
25bad		X	X1				X1					
26aaa		X		X		X		X		X		X
26abb		X		X		X		X		X		X
27bbd		X		X		X		X		X		X

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Yes	Water Table Hydrographs Calculated No	Yes	Crop Affected By Water Table No	Yes	Post-Project: Piezometric Hydrograph Developed No	Yes	Water Table Hydrographs Calculated No	Yes	Crop Affected By Water Table No	Yes
T6S-R8W												
27dbb		X		X		X		X		X		X
28bcb		X		X	X			X		X		X
28bdb		X		X	X			X		X		X
30bdb		X		X	X			X		X		X
30dab		X		X	X			X		X		X
31bab		X		X		X		X		X		X
31caa		X		X		X		X		X		X
33bab		X		X		X		X		X		X
33dad		X		X		X		X		X		X
T7S-R8W												
1aaa		X		X		X		X		X		X
5bca		X		X		X		X		X		X
6bba		X		X	X			X		X		X
7cca		X		X	X			X		X		X
10ccb		X		X		X		X		X		X
19dcd		X		X	X			X		X		X
23dcc		X		X	X			X		X		X
32aaa		X		X	X			X		X		X
33acd		X		X	X			X		X		X
34adc		X		X	X			X		X		X
35acc		X		X	X			X		X		X
T8S-R8W												
10ccc		X	X1				X1					
12dac		X	X1				X1					
16abc		X	X1				X1					
17acb		X	X1				X1					
T4N-R9W												
28ccd	X4						X4					
36daa	X4						X4					
T2N-R9W												
28ccc	X4						X4					
T1S-R9W												
3cdc	X1						X1					
6ccc	X1						X1					
7aaa	X1						X1					
9abb	X1						X1					
11bab	X1						X1					
16acc	X1						X1					
17cbb	X1						X1					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Yes	Water Table Hydrographs Calculated No	Yes	Crop Affected By Water Table No	Yes	Post-Project: Piezometric Hydrograph Developed No	Yes	Water Table Hydrographs Calculated No	Yes	Crop Affected By Water Table No	Yes
T1S-R9W												
18bac	X1						X1					
23ada	X1						X1					
29bac	X1						X1					
30bbd	X1						X1					
31bcb	X1						X1					
31dac	X1						X1					
34cac	X1						X1					
36daa	X1						X1					
36dad	X1						X1					
T2S-R9W												
2abb	X1						X1					
5aad	X1						X1					
11ddc	X1						X1					
12ccc	X1						X1					
16bbb	X1						X1					
17bcb	X1						X1					
18cab	X1						X1					
21bba	X1						X1					
22bba	X1						X1					
24bab	X1						X1					
24caa	X1						X1					
31add	X1						X1					
32cda	X1						X1					
33abb	X1						X1					
33cca	X1						X1					
35aba	X1						X1					
35cab	X1						X1					
35dbb	X1						X1					
36aaa	X1						X1					
T3S-R9W												
14cac		X	X1				X1					
14dcc		X	X1				X1					
14ddd		X	X1				X1					
19cba	X1						X1					
20ccd		X	X1				X1					
21adb		X	X1				X1					
22bab		X	X1				X1					
24bbc		X	X1				X1					
31dda	X1						X1					
T4S-R9W												
31bdb		X	X1				X1					
31cba		X	X1				X1					
31dac		X	X1				X1					
32abc		X	X1				X1					

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	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T5S-R9W												
7bac		X		X		X		X		X		X
7ccc		X	X1				X1					
7dbb		X	X1				X1					
8bcc		X		X	X			X		X		X
17abb		X		X	X			X		X	X	
17cca		X		X	X			X		X		X
18adb		X		X		X		X		X		X
18bcc	X1						X1					
19abc	X1						X1					
19dbb	X1						X1					
20abb		X	X1					X		X	X	
20dba		X	X1					X		X	X	
21ccd		X	X1					X		X	X	
29bcc	X1						X1					
29dda		X		X	X			X		X	X	
30aaa		X	X1				X4					
30dca	X4						X4					
31ccc	X4						X4					
31daa	X4						X4					
32aad	X4						X4					
32ddc	X4						X4					
34ccb	X4						X4					
35baa	X4						X4					
T6S-R9W												
7add	X4						X4					
8dda	X4						X4					
9abb	X4						X4					
11ccc	X4						X4					
11dda	X4						X4					
12adb	X4						X4					
15ccb	X4						X4					
15dad	X4						X4					
17bad	X4						X4					
17dbd	X4						X4					
18cad	X4						X4					
20bcd	X4						X4					
22cdc	X4						X4					
26ddb	X4						X4					
27aaa	X4						X4					
29aaa	X4						X4					
32cab	X4						X4					
36bac	X4						X4					

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	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T7S-R9W												
2bca	X4						X4					
23dba	X4						X4					
T2N-R10W												
5bcc		X	X1				X1					
16bac		X	X1				X1					
16ccc		X	X1				X1					
20cca		X		X	X			X		X	X	
29cbd	X4						X4					
29dbc	X4						X4					
30bda	X4						X4					
T1N-R10W												
4abd		X	X1				X1					
17bcb		X	X1				X1					
20bcb		X	X1					X		X	X	
28bbc		X	X1				X1					
29ddb		X	X1				X1					
30bac		X	X1				X1					
30cdc		X	X1				X1					
31aac		X	X1				X1					
31bad		X		X		X		X		X		X
31cdb		X	X1				X1					
32cbb		X	X1				X1					
33cca		X		X		X		X		X		X
T1S-R10W												
1acb		X	X1				X1					
1bda		X	X1				X1					
2bbb		X		X	X			X		X		X
4cbb		X	X1				X1					
5cca		X	X1				X1					
6add		X	X1				X1					
6dcc		X		X	X			X		X	X	
7bdc		X		X		X		X		X		X
17bad		X		X	X			X		X		X
18bdd		X		X	X			X		X		X
19ddb		X		X	X			X		X		X
20dba	X4						X4					
22ddd		X	X1				X1					
25bad		X	X1				X1					
26adb		X	X1				X1					
26baa		X	X1				X1					
30bdd		X	X1				X1					
32ccb		X		X	X			X		X		X

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Piezometer Location	Pre-Project: Piezometer Data Interpolated		Pre-Project: Water Table Hydrographs Calculated		Pre-Project: Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Post-Project: Water Table Hydrographs Calculated		Post-Project: Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T2S-R10W												
3cac		X	X1				X1					
10bda		X	X1				X1					
13dda		X	X1				X1					
14dca		X	X1				X1					
15cdd		X	X1				X1					
16baa		X	X1				X1					
16caa		X	X1				X1					
21bbb		X	X1				X1					
22bba		X	X1				X1					
25dcb		X	X1				X1					
26adc		X	X1				X1					
26bab		X	X1				X1					
33bbb		X		X	X			X		X		X
T3S-R10W												
2abd		X		X	X			X		X		X
2bbc		X		X	X			X		X		X
4bbd		X		X	X			X		X		X
13abb		X		X	X			X		X		X
13cca		X		X	X			X		X		X
23bcc		X		X	X			X		X		X
23cad		X		X	X			X		X		X
26cbc		X		X	X			X		X		X
35aaa		X		X	X			X		X		X
35bba		X		X	X			X		X		X
36aad		X		X	X			X		X		X
36bbc		X		X	X			X		X	X	
T4S-R10W												
1cbd		X	X1				X1					
2cbd		X	X1				X1					
T5S-R10W												
12abc	X1						X1					
25ada	X1						X1					
25cbd	X1						X1					
34ddd	X1						X1					
35aab	X1						X1					
T5N-R11W												
8bac	X4						X4					
T4N-R11W												
14bab	X4						X4					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated: No	Pre-Project: Piezometer Data Interpolated: Yes	Pre-Project: Water Table Hydrographs Calculated: No	Pre-Project: Water Table Hydrographs Calculated: Yes	Pre-Project: Crop Affected By Water Table: No	Pre-Project: Crop Affected By Water Table: Yes	Post-Project: Piezometric Hydrograph Developed: No	Post-Project: Piezometric Hydrograph Developed: Yes	Post-Project: Water Table Hydrographs Calculated: No	Post-Project: Water Table Hydrographs Calculated: Yes	Post-Project: Crop Affected By Water Table: No	Post-Project: Crop Affected By Water Table: Yes
T3N-R11W												
3acc	X4						X4					
T3N-R11W												
29aad	X4						X4					
T2N-R11W												
15cdc	X4						X4					
23cdc	X4						X4					
24dcc	X4						X4					
25abb	X4						X4					
T1N-R11W												
1ddc		X		X	X			X		X	X	
2bcb		X	X4					X	X4			
8cab		X	X1				X1					
9ccc		X	X1				X1					
10abb		X	X1					X	X1			
15bab		X		X		X		X		X		X
15ccd		X		X	X			X		X	X	
16aad		X	X1				X1					
16abd		X	X1				X1					
20acb		X		X	X			X		X	X	
20dad	X1						X1					
21dac	X1						X1					
21dba		X	X4				X4					
22dbc		X		X	X			X		X	X	
23dcb		X	X1				X1					
24aad		X	X1				X1					
25aad		X	X1				X1					
26cba		X	X1				X1					
27dbb	X4						X4					
28adc	X4						X4					
28daa		X		X	X			X		X	X	
28dca		X	X1				X1					
29acd		X	X4				X4					
29bcc	X4						X4					
29bbc	X4						X4					
29cab	X4						X4					
29cdb	X4						X4					
29dcb	X4						X4					
30aac	X4						X4					
30abb	X4						X4					
30dba	X4						X4					
30dbc		X	X4				X4					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated — No	Yes	Water Table Hydrographs Calculated — No	Yes	Crop Affected By Water Table — No	Yes	Post-Project: Piezometric Hydrograph Developed — No	Yes	Water Table Hydrographs Calculated — No	Yes	Crop Affected By Water Table — No	Yes
T1N-R11W												
31acb		X	X4				X4					
32adc	X4						X4					
32bca		X	X4				X4					
32cdc		X	X4				X4					
33dba		X		X		X		X		X		X
33dbc	X4						X4					
34aba		X		X	X			X		X	X	
34cdd		X		X	X			X		X	X	
36dcb		X		X	X			X		X		X
T1S-R11W												
4aab		X		X		X		X		X		X
4add		X		X		X		X		X		X
4dca		X		X		X		X		X		X
5dab		X	X4				X4					
6caa	X1						X1					
8bdc		X	X4				X4					
9caa		X	X4				X4					
9ccb		X	X4				X4					
10acd		X	X1				X1					
10cab		X	X4				X4					
15dad		X	X1				X1					
15dba		X	X1				X1					
16abd		X	X2				X2					
16cbb		X	X4				X4					
16cdd		X	X2				X2					
17bcd		X	X1				X1					
17bdc		X	X2				X2					
20dcc	X4						X4					
21bbd		X		X	X		X2					
23cba		X	X1				X1					
25ddb		X	X1				X1					
28add		X		X	X			X		X		X
28cbb		X		X	X			X		X		X
29cbb	X1						X1					
33acd		X		X	X			X		X		X
T2S-R11W												
3cdd		X		X		X		X		X		X
4aaa		X		X	X			X		X	X	
5aba		X	X1				X1					
9dcc		X		X		X		X		X		X
10aaa		X	X1				X1					
10cdd		X		X	X			X		X		X
15ddc		X		X	X			X		X	X	

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	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T2S-R11W												
17bac	X4						X4					
20bdd	X4						X4					
21aac		X		X	X			X		X		X
21bac		X	X1				X1					
23bcc		X	X1				X1					
23dab	X4						X4					
25ccd		X	X1				X1					
26dbb		X	X1				X1					
26dcc		X	X1				X1					
27cdd		X		X	X			X		X		X
T2N-R12W												
17aac	X4						X4					
19baa		X	X1				X1					
19bbc		X	X1				X1					
19cdd		X	X1				X1					
29adc		X	X1				X1					
29dbb		X		X	X		X1					
30aaa		X	X1				X1					
#4		X	X1				X1					
T4N-R13W												
30aad	X4						X4					
30bca	X4						X4					
T3N-R13W												
13dcd		X	X1				X1					
25aca	X4						X4					
30bbc		X		X	X		X1					
30cbb		X		X		X		X		X		X
30cbc		X		X		X		X		X		X
T2N-R13W												
7dba	X4						X4					
7ddc	X4						X4					
8cdd		X		X		X		X		X		X
10cad		X		X	X			X		X		X
13adc		X		X	X		X1					
13ccb		X	X1				X1					
13dcc		X	X1				X1					
16bac		X		X	X			X		X		X
16bbb		X		X	X			X		X	X	
16cbc		X		X	X			X		X		X
16dca		X		X	X			X		X		X

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Yes	Pre-Project: Water Table Hydrographs Calculated No	Yes	Pre-Project: Crop Affected By Water Table No	Yes	Post-Project: Piezometric Hydrograph Developed No	Yes	Post-Project: Water Table Hydrographs Calculated No	Yes	Post-Project: Crop Affected By Water Table No	Yes
T1N-R13W												
11bbd	X4						X4					
T5N-R14W												
19cdc		X	X1				X1					
19dcc		X	X1				X1					
20ccc		X	X1				X1					
30abc		X	X1				X1					
30bca		X	X1				X1					
30daa		X	X1				X1					
30dbc		X		X	X		X1					
31cdd		X		X	X		X2					
T4N-R14W												
19ada		X	X1				X1					
28caa		X	X1				X1					
29abb		X	X1				X1					
29dbc		X	X1				X1					
T3N-R14W												
2ccb		X		X	X		X1					
3daa		X	X1				X1					
3dbb		X		X	X		X1					
3ddd												
10aba		X		X		X		X		X		X
10bab		X		X	X		X1					
10cbc		X	X1				X1					
10ddb		X		X		X		X		X		X
11cdd		X		X		X		X		X		X
14bcc		X		X		X		X		X		X
14cab		X		X	X		X1					
15bbd	X4						X4					
15dbc		X		X		X		X		X		X
15dda		X		X		X		X		X		X
16bdb		X	X1				X1					
16dcd		X	X4				X4					
22aaa		X		X		X		X		X		X
22aad		X		X	X		X1					
22abb		X		X		X		X		X		X
22add		X		X		X		X		X		X
22bbd		X	X4				X4					
22cca	X4						X4					
22ddb		X		X		X		X		X		X
23bab		X	X1				X1					
26ccd		X	X4				X4					
35acd		X		X		X		X		X		X
35baa		X	X4				X4					
35bac	X4						X4					
36cbc		X		X		X		X		X		X

Piezometer Location	Pre-Project: Piezometer Data Interpolated		Pre-Project: Water Table Hydrographs Calculated		Pre-Project: Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Post-Project: Water Table Hydrographs Calculated		Post-Project: Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T2N-R14W												
17bda	X4						X4					
30cdd	X4						X4					
35dcb	X4						X4					
T6N-R15W												
19dab		X		X		X		X		X		X
20cda		X		X	X		X1					
21cdd		X	X1				X1					
25aca	X4						X4					
25bbd		X	X1				X1					
26aab		X	X1				X1					
27aaa		X	X2				X2					
27bac		X	X2				X2					
28dab		X	X2				X2					
29adc		X	X2				X2					
30aab		X		X		X		X		X	X	
30bbc		X	X1				X1					
30dbb		X	X1				X1					
31adc		X		X	X		X2					
31bda		X	X1				X1					
31cbb		X	X1				X1					
32dca		X	X1				X1					
33bab		X	X1				X1					
33dad		X		X	X		X1					
34dac		X	X1				X1					
35adb		X		X	X			X		X		X
T5N-R15W												
3bca		X		X	X		X1					
4abb		X		X	X			X		X	X	
4dba		X	X1				X1					
5aaa		X	X1				X1					
7ddd		X	X1				X1					
8cbb		X	X1				X1					
8ddc		X	X1				X1					
9bad		X	X1				X1					
12cbb		X	X1				X1					
12dbb		X	X1				X1					
13acc		X	X1				X1					
23ddb	X4						X4					
25dda		X	X1				X1					
26aca		X	X1				X1					
26ada		X	X1				X1					
36caa		X	X1				X1					
36daa		X	X1				X1					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated — No	Yes	Pre-Project: Water Table Hydrographs Calculated — No	Yes	Pre-Project: Crop Affected By Water Table — No	Yes	Post-Project: Piezometric Hydrograph Developed — No	Yes	Post-Project: Water Table Hydrographs Calculated — No	Yes	Post-Project: Crop Affected By Water Table — No	Yes
T4N-R15W												
1adb		X		X	X		X1					
1cda		X		X		X	X2					
1cdb		X		X		X	X2					
1dac		X		X		X	X2					
1ddc		X		X		X	X2					
2bdc		X	X1				X1					
2ccb		X	X1				X1					
10aba		X	X1				X1					
11cbb		X		X	X		X1					
13ada		X		X	X		X1					
13bcb		X	X1				X1					
14bac		X	X1				X1					
15aca		X	X1				X1					
23bac		X	X1				X1					
24bcc		X		X	X		X1					
24cad		X	X1				X1					
24dda		X	X1				X1					
25adb		X	X1				X1					
T3N-R15W												
35aac	X4						X4					
T6N-R16W												
31acb		X	X1				X1					
31dac		X	X1				X1					
32aad		X	X1				X1					
34bcb		X		X		X	X2					
35aad		X		X	X		X2					
35cbb		X	X1				X1					
35daa		X		X	X		X2					
T5N-R16W												
2cbb		X		X		X		X		X	X	
3caa		X		X	X		X2					
4aba		X		X	X		X2					
4bbb		X	X1				X1					
6abc		X	X1				X1					
6bcd	X4						X4					
9abc		X	X1				X1					
9dbb		X	X1				X1					
10acc		X	X1				X1					
10ada		X	X1				X1					
T7N-R17W												
32cda		X		X		X	X2					

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Piezometer Location	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T6N-R17W												
4cad		X	X1				X1					
5bdc		X		X		X	X2					
5bdd		X	X1				X1					
6adc		X	X1				X1					
6caa		X	X1				X1					
7adc		X	X1				X1					
7cbb		X	X1				X1					
7ddd		X	X1				X1					
9bbc		X	X1				X1					
9cbc		X	X1				X1					
15bbc		X	X1				X1					
15cbd		X	X1				X1					
15dbd		X	X1				X1					
16baa		X	X1				X1					
16dad		X	X1				X1					
17caa		X	X1				X1					
19aca		X	X1				X1					
19bbb		X	X1				X1					
19bcc		X	X1				X1					
20aca		X	X1				X1					
21ada		X	X1				X1					
21dda		X	X1				X1					
25ddc		X	X1				X1					
26aaa		X	X1				X1					
27bdd		X	X1				X1					
27cbb		X	X1				X1					
28bbd		X	X1				X1					
32cdd		X	X1				X1					
T6N-R17W												
34abc		X	X1				X1					
35bdd		X	X1				X1					
36acd		X	X1				X1					
36bcb		X	X1				X1					
T5N-R17W												
1aab		X		X	X		X1					
1bbb		X	X1				X1					
4bcc		X	X1				X1					
4bdd		X	X1				X1					
4ccb		X		X	X			X		X	X	
5abc		X	X1				X1					
5cdd		X	X1				X1					
9bbc		X	X1				X1					
19bbc	X4						X4					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated — No	Yes	Water Table Hydrographs Calculated — No	Yes	Crop Affected By Water Table — No	Yes	Post-Project: Piezometric Hydrograph Developed — No	Yes	Water Table Hydrographs Calculated — No	Yes	Crop Affected By Water Table — No	Yes
T5N-R17W												
19dcd	X4						X4					
20aaa	X4						X4					
22cbd	X4						X4					
23dda	X4						X4					
24aad	X4						X4					
27dbd	X4						X4					
29aca	X4						X4					
T7N-R18W												
23ccb	X4						X4					
28dba	X4						X4					
T6N-R18W												
1adc		X		X	X		X1					
2adc		X	X1				X1					
2bcb		X	X1				X1					
2ccb		X		X	X		X1					
9bad		X		X	X		X1					
9bcb		X	X1				X1					
9dbb		X	X1				X1					
9dbd		X		X	X		X1					
12bdc		X	X1				X1					
24dab		X	X1				X1					
T6N-R19W												
23bbb		X	X1				X1					
23ccc		X	X1				X1					
24acb		X	X1				X1					
24bbc		X	X1				X1					
25aaa		X	X1				X1					
T8N-R20W												
31dbc		X	X4				X4					
32cba		X	X4				X4					
T8N-R21W												
25dda	X5						X5					
T9N-R24W												
19cdd		X	X1				X1					
31bbb		X		X		X		X		X		X

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Piezometer Location	Pre-Project: Piezometer Data Interpolated: No	Pre-Project: Piezometer Data Interpolated: Yes	Pre-Project: Water Table Hydrographs Calculated: No	Pre-Project: Water Table Hydrographs Calculated: Yes	Pre-Project: Crop Affected By Water Table: No	Pre-Project: Crop Affected By Water Table: Yes	Post-Project: Piezometric Hydrograph Developed: No	Post-Project: Piezometric Hydrograph Developed: Yes	Post-Project: Water Table Hydrographs Calculated: No	Post-Project: Water Table Hydrographs Calculated: Yes	Post-Project: Crop Affected By Water Table: No	Post-Project: Crop Affected By Water Table: Yes
T9N-R25W												
24adb		X	X5					X	X5			
25acc		X		X		X		X		X		X
26dcc		X	X1				X1					
31cbc		X	X1				X1					
32bba		X	X1				X1					
32bcb		X	X1				X1					
32ccb		X	X1				X1					
T8N-R25W												
1abb		X	X1				X1					
2abb		X	X1				X1					
4ddd		X	X1				X1					
5ddd		X	X1				X1					
7daa		X	X1				X1					
8aad		X	X1				X1					
8abb		X	X1				X1					
8add		X	X1				X1					
8ddd		X	X1				X1					
9dad		X	X1				X1					
10acc		X	X1				X1					
10bcb		X	X1				X1					
17caa		X	X1				X1					
17ccc		X	X1				X1					
17dca		X	X1				X1					
17dcb		X	X1				X1					
18ada		X	X1				X1					
18add		X	X1				X1					
18baa		X	X1				X1					
18bbb		X	X1				X1					
18bcc		X	X1				X1					
18ccc		X	X1				X1					
19aaa		X		X		X	X2					
19aba		X	X1				X1					
19abd		X	X1				X1					
19acb		X	X1				X1					
19bcc		X	X1				X1					
19ccc		X	X1				X1					
20bcc		X	X1				X1					
20ccc		X	X1				X1					
20ddd		X	X1				X1					
21bca		X	X1				X1					
30bbc		X		X		X	X2					
T9N-R26W												
26ddd		X		X		X	X4					
35ddd		X	X1				X1					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated: No	Yes	Water Table Hydrographs Calculated: No	Yes	Crop Affected By Water Table: No	Yes	Post-Project: Piezometric Hydrograph Developed: No	Yes	Water Table Hydrographs Calculated: No	Yes	Crop Affected By Water Table: No	Yes
T8N-R26W												
1add		X	X1				X1					
1cbb		X	X1				X1					
2bbb		X	X1				X1					
2cbc		X	X1				X1					
13baa		X	X1				X1					
13cdd		X	X1				X1					
14aac		X	X1				X1					
14aad		X	X1				X1					
14add	X4						X4					
14bdd		X	X1				X1					
15ada		X	X1				X1					
15adc		X	X1				X1					
15bdd		X	X1				X1					
15cad		X	X1				X1					
15cdc		X	X1				X1					
15dab		X	X1				X1					
21aad		X	X1				X1					
21aba		X	X1				X1					
23aba		X	X1				X1					
23aca		X	X1				X1					
23bbb		X	X1				X1					
24ccc		X	X1				X1					
24cdd		X	X1				X1					
T9N-R27W												
2cdc		X	X1				X5					
9dbc		X	X1				X3					
T10N-R29W												
32ddd		X		X		X	X3					
T9N-R29W												
3add		X	X1				X3					
3bcc		X	X2				X3					
6add		X		X		X	X3					
8add		X		X		X	X3					
9add		X		X	X		X3					
10ada		X		X		X	X3					
11bcc		X		X		X	X3					
12aaa		X		X		X	X3					
12bba		X	X1				X3					
14bcb		X	X1				X3					
15aaa		X		X		X	X3					
15bcb		X		X	X		X3					
16aba		X		X		X	X3					
17bdd		X		X		X	X3					
19dcb		X		X	X		X3					
29bda		X		X	X		X3					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Pre-Project: Piezometer Data Interpolated Yes	Pre-Project: Water Table Hydrographs Calculated No	Pre-Project: Water Table Hydrographs Calculated Yes	Pre-Project: Crop Affected By Water Table No	Pre-Project: Crop Affected By Water Table Yes	Post-Project: Piezometric Hydrograph Developed No	Post-Project: Piezometric Hydrograph Developed Yes	Post-Project: Water Table Hydrographs Calculated No	Post-Project: Water Table Hydrographs Calculated Yes	Post-Project: Crop Affected By Water Table No	Post-Project: Crop Affected By Water Table Yes
T9N-R30W												
12ccc		X		X	X		X3					
15dbb		X		X		X	X3					
25ccb		X	X1				X3					
25daa		X	X1				X3					
26cba		X	X1				X3					
26cdd		X	X1				X3					
33ccb		X		X		X	X3					
33dbd		X		X		X	X3					
34dad		X		X	X		X3					
35bba		X	X1				X3					
35cda		X	X1				X3					
36aad		X	X1				X3					
36dca		X	X1				X3					
T8N-R30W												
1cad		X	X1				X3					
2acb		X	X1				X3					
2baa		X	X1				X3					
3aad		X		X		X	X3					
3add		X	X1				X3					
4aca		X	X1				X3					
4cbc		X	X1				X3					
6acc		X		X		X	X3					
6ccc		X	X1				X3					
6dbb		X	X1				X3					
8aaa		X	X1				X3					
8aba		X		X		X	X3					
8adc		X	X1				X3					
8bab		X		X		X	X3					
11abb		X		X	X		X3					
13aad		X	X1				X3					
13acd		X	X1				X3					
13bcd		X	X1				X3					
13cac		X	X1				X3					
13ccc		X	X1				X3					
13dbd		X	X1				X3					
14add		X	X1				X3					
14dda		X	X1				X3					
15dbb		X	X1				X3					
15ddd		X	X1				X3					
15ddd		X		X		X	X3					
18bdd		X	X1				X3					
19bbd		X	X1				X3					
21caa		X	X1				X3					
22bad		X		X	X		X3					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated		Pre-Project: Water Table Hydrographs Calculated		Pre-Project: Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Post-Project: Water Table Hydrographs Calculated		Post-Project: Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T9N-R31W												
29ccc		X	X1				X1					
30daa		X	X1				X1					
30dbb		X	X1				X1					
30dcb		X	X1				X1					
T8N-R31W												
1cad		X		X	X		X1					
4cac		X	X1				X1					
5bcb		X		X	X			X		X		X
5ccc		X	X1				X1					
8bcb		X	X1				X1					
9bcc		X	X1				X1					
11bcc		X	X1				X1					
12bbc		X		X	X		X1					
12cbc		X		X	X		X1					
12ddc		X	X1				X1					
13bbb		X	X1				X1					
14ada		X	X1				X1					
14bab		X		X	X		X1					
15daa		X	X1				X1					
16abd		X	X1				X1					
16cbc		X	X1				X1					
16daa		X	X1				X1					
16dcc		X	X1				X1					
17bda		X	X1				X5					
22aab		X	X1				X1					
24bbb		X	X1				X1					
T9N-R32W												
15dcb		X	X1				X1					
22aba		X	X1				X1					
28daa		X	X1				X1					
33baa		X	X1				X1					
36cba		X	X1				X1					
T8N-R32W												
1bba		X	X1				X1					
1bbd		X		X		X		X		X		X
1cdc		X		X	X		X1					
12bca		X	X1				X1					
12bda		X		X		X		X		X		X
13aaa		X	X1				X5					

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Piezometer Location	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Oklahoma												
T11N-R27E												
9dbb		X		X		X	X4					
15bba		X		X		X	X4					
15cdc		X	X1				X1					
20aaa		X		X		X	X4					
20bbc		X		X		X	X4					
20ddd		X		X		X	X4					
21bcb		X		X		X	X4					
21cdd		X		X		X	X4					
27bbb		X	X1				X1					
27bcb		X	X1				X1					
27dcc		X	X1				X1					
28abb		X	X1				X1					
T10N-R27E												
3cab		X		X		X		X		X		X
9abc		X		X		X		X		X		X
9bbc		X	X4				X4					
T10N-R26E												
16caa		X	X1				X1					
17abb		X	X4				X4					
17add		X	X1				X1					
33abc		X	X1				X1					
T9N-R26E												
6bbc		X	X4				X4					
6cbc		X	X4				X4					
7bbc		X	X4				X4					
T9N-R25E												
1aaa		X	X1				X1					
1cdb		X	X1				X1					
4caa		X	X				X					
6abb		X	X4				X4					
6ddd		X	X1				X1					
T10N-R24E												
7cbc		X	X5				X5					
8ccb		X	X5				X5					
16acd		X	X1				X1					
16baa		X	X1				X1					
16dba		X	X1				X1					
18dab		X	X5				X5					

	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrographs Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T11N-R23E												
19bcc		X	X5				X5					
31cdd		X	X5				X5					
32bad		X	X5				X5					
32dcd		X	X5				X5					
T10N-R23E												
3bbb		X	X5				X5					
4bcc		X	X5				X5					
4dac		X	X5				X5					
8abc		X	X5				X5					
9baa		X	X5				X5					
9bcc		X	X5				X5					
9cdc		X	X5				X5					
10cca		X	X5				X5					
11bbc		X	X5				X5					
11dcc		X	X5				X5					
12cbb		X	X5				X5					
13ada		X	X5				X5					
14cbb		X	X5				X5					
15bdc		X	X5				X5					
16cbb		X	X5				X5					
16dab		X	X5				X5					
22baa		X	X5				X5					
T11N-R22E												
4ddd		X	X5				X5					
5dad		X	X5				X5					
8ccc		X	X5				X5					
9cbb		X	X5				X5					
10ccc		X	X5				X5					
10dad	X5						X5					
14aaa	X5						X5					
15daa	X5						X5					
16bbb	X5						X5					
17add		X	X5				X5					
23bdb	X5						X5					
24bbb	X5						X5					
24ccb	X5						X5					
34ddd	X5						X5					
35ddd		X	X5				X5					
T10N-R22E												
1ddd	X5						X5					
11aaa	X5						X5					
11bba	X5						X5					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Pre-Project: Piezometer Data Interpolated Yes	Pre-Project: Water Table Hydrographs Calculated No	Pre-Project: Water Table Hydrographs Calculated Yes	Pre-Project: Crop Affected By Water Table No	Pre-Project: Crop Affected By Water Table Yes	Post-Project: Piezometric Hydrograph Developed No	Post-Project: Piezometric Hydrograph Developed Yes	Post-Project: Water Table Hydrographs Calculated No	Post-Project: Water Table Hydrographs Calculated Yes	Post-Project: Crop Affected By Water Table No	Post-Project: Crop Affected By Water Table Yes
T12N-R21E												
29ddd		X	X1				X1					
30aaa		X	X1				X1					
31bbb		X	X5				X5					
31cbb		X	X5				X5					
32bbb		X	X5				X5					
33ccb		X	X5				X5					
T11N-R21E												
1add		X	X5				X5					
5bbb		X	X5				X5					
5dda		X	X5				X5					
9bab		X	X5				X5					
T12N-R20E												
11aaa		X	X5				X5					
11bba		X	X5				X5					
13ddc		X	X5				X5					
24baa		X	X5				X5					
24ddd		X	X5				X5					
T16N-R19E												
19ccc		X	X5				X5					
30abb		X	X5				X5					
31abd		X	X5				X5					
31ccd		X	X5				X5					
32dcc		X	X5				X5					
33bcc		X	X4				X4					
T15N-R19E												
9daa		X	X5				X5					
11bab		X	X5				X5					
11bcc		X	X5				X5					
11daa		X	X4				X4					
13bba		X	X4				X4					
14aad		X	X5				X5					
15aaa		X	X5				X5					
15ddd		X	X5				X5					
16aaa		X	X5				X5					
16add		X	X5				X5					
16dcc		X	X5				X5					
21dcc		X	X5				X5					
22acb		X	X5				X5					
22bbb		X	X5				X5					
23ddd		X	X5				X5					
24baa		X	X5				X5					
24bbb		X	X5				X5					
24ddd		X	X5				X5					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated No	Yes	Pre-Project: Water Table Hydrographs Calculated No	Yes	Pre-Project: Crop Affected By Water Table No	Yes	Post-Project: Piezometric Hydrograph Developed No	Yes	Post-Project: Water Table Hydrographs Calculated No	Yes	Post-Project: Crop Affected By Water Table No	Yes
T15N-R19E												
26bbb		X	X5				X5					
27bcc		X	X5				X5					
27dad		X	X5				X5					
28aaa		X	X5				X5					
T14N-R19E												
24abb		X	X5				X5					
24add		X	X5				X5					
24ccc		X	X5				X5					
24ddc	X5						X5					
25abb		X	X5				X5					
25cdc		X	X5				X5					
34ddd		X	X5				X5					
35baa		X	X5				X5					
35cda		X	X5				X5					
35cdd		X	X5				X5					
35dcc		X	X5				X5					
35ddc		X	X5				X5					
T13N-R19E												
2aaa		X	X1					X		X	X	
2cdc		X	X5				X5					
3aaa		X	X5				X5					
12bbb		X	X5				X5					
12caa		X	X5				X5					
12cbb		X	X5				X5					
12cdd		X	X5				X5					
T17N-R18E												
31dda		X		X	X			X		X		X
31ddc		X		X	X			X		X		X
32cbb		X		X		X		X		X		X
T16N-R18E												
5baa		X		X	X			X		X		X
9bbb		X		X	X			X		X		X
9dac		X		X		X		X		X		X
11bcc		X	X1				X1					
11cdd		X	X1				X1					
13bba	X4						X4					
14aba		X		X	X			X		X	X	
15aaa		X	X1					X	X1			
15bba		X	X1				X5					
15ddc		X	X1				X1					

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Piezometer Location	Pre-Project: Piezometer Data Interpolated		Pre-Project: Water Table Hydrograph Calculated		Pre-Project: Crop Affected By Water Table		Post-Project: Piezometric Hydrograph Developed		Post-Project: Water Table Hydrographs Calculated		Post-Project: Crop Affected By Water Table	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
T16N-R18E												
21bba		X	X4				X4					
22aaa		X	X1				X1					
22bcb		X	X1				X1					
22dad		X	X1				X1					
23bba		X	X1				X1					
23bdb		X	X1				X1					
23dad		X	X1				X1					
24aad		X	X1				X1					
33cad		X	X1				X1					
35bcb		X	X1				X1					
35ddd		X	X1				X1					
T19N-R17E												
31cdd		X	X1				X1					
T18N-R17E												
6aad		X	X1				X1					
6cbb		X	X1					X		X		X
7dcc		X	X				X					
8bbb		X		X	X			X		X		X
9bcd		X	X1				X1					
16bbb		X	X				X					
18bbb	X4						X4					
T17N-R17E												
4ccc		X		X	X			X		X		X
7dbc		X		X	X			X		X	X	
9ccc		X		X		X		X		X	X	
10cbc		X		X		X		X		X		X
18dba		X		X	X			X		X	X	
19ada		X		X		X		X		X		X
21aaa		X	X1				X1					
21dcd		X	X4				X4					
22ada		X	X1				X1					
24bbb		X		X		X		X		X		X
24ccc		X	X1					X		X		X
24dcd		X		X	X			X		X		X
26bbb		X	X1				X1					
26ccb		X		X		X		X		X		X
27dab		X		X	X			X		X		X
33aaa		X		X		X		X		X		X
33aac		X		X		X		X		X		X
34abb		X		X	X			X		X		X
35aab		X		X		X		X		X		X
36daa		X	X1					X		X		X

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	Pre-Project						Post-Project					
	Piezometer Data Interpolated		Water Table Hydrograph Calculated		Crop Affected By Water Table		Piezometric Hydrograph Developed		Water Table Hydrographs Calculated		Crop Affected By Water Table	
Piezometer Location	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
			1/									
T16N-R17E												
1aaa 2/		X		X	X			X		X		X
T19N-R16E												
20aaa		X	X1				X1					
20bbb		X	X1				X1					
20ddd		X	X1				X1					
22bbb		X	X4				X4					
22ccc		X	X1					X		X		X
23acc		X	X1				X1					
26baa		X	X1					X		X		X
26cdd		X	X1					X		X		X
27dcc		X	X1					X		X		X
30aaa		X	X4				X4					
36bbb		X	X1					X		X		X
T18N-R16E												
1aaa		X		X	X			X		X		X
11daa		X	X2				X2					
12abb		X		X		X		X		X		X
13aab		X	X4				X4					
13bbb		X	X1				X1					
13bcc		X	X1				X1					
13daa		X	X4				X4					
14baa		X	X1				X1					

1/ Numbers after X's
1. Not required because of depth.
2. < 1.5' change in Piezometric Surface.
3. Post-Project Data unavailable.
4. Does not correlate with River stage.
5. C.E. purchase or easement.

2/ Township, range, section, and location within the section. "a" is NE$\frac{1}{4}$, "b" is in the NW$\frac{1}{4}$, "c" is in the SW$\frac{1}{4}$, and "d" is in the SE$\frac{1}{4}$. The $\frac{1}{4}$ sections are indicated by the second letter and the third letter locates it in the 1/16th section.

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Texture	K (ft. / day)
Clay and silty clay	0.001
Silty clay loam, clay loam sandy clay loam, and sandy clay	0.01
Silt loam, silt, and loam	0.1
Sands, sandy loams, and loamy sands	1.0

Most of the surface materials down river from Little Rock had K values of 0.001 feet per day as typified in the Figure 9 example. These K values and the base elevations as used in the equation are shown in the sample water table and piezometric hydrographs in the "Effects" section of this report.

The drainable or fillable porosity (f) values that were used in the water table calculations were 0.05 for very-fine-textured soil, and 0.10 for fine-and medium-textured soils. The f value depends upon the direction and the water table is moving, soil texture, soil structure, root channels, compaction, A values, soil cracks, etc.

The practical length of time (t_2-t_1) used to determine h_2 by the equation depends upon the relationship of the fluctuation of the water table and the piezometric surface and upon the rate of rise and fall of the piezometric surface. In this study not more than 30 nor less than 5 days lapse time were used in the calculation of the water table.

The final variable in the equation is the "A" value, or the accretion or removal of water from the surface of the water tables. Items affecting the "A" values are listed and followed by a detailed discussion below.

Accretion of rainfall to the water table was accounted for, directly or indirectly by: intensity of rainfall (24-hour), preceding condition, duration of rainfall period, total rainfall, effective rainfall, soil texture, soil permeability, soil moisture status, and soil structure. Factors considered but not evaluated were: temperature (as it influences soil permeability), form of precipitation (rain, snow, hail, dew), surface drainage, soil cover, surface compaction, surface ponding, surface soil slope, micro-stratification of the soil, and soil salts, - there are probably others.

Factors which removed water directly from the water table (evapotranspiration) were influenced by: stage of plant growth, root development, depth of the water table, type of crop, soil moisture holding capacity, available soil moisture, soil moisture extraction pattern, solar radiation, and pan evaporation. The following were indirectly considered in the above factors: leaf area, relative humidity, temperature, sky cover, wind speed, and day length. Not accounted for were: capillary fringe, and luxury consumption of water from the water table by plants.

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Figure 9

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERMEABILITY MAP (Sample)

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The details of how these factors were evaluated in arriving at the net "A" values are given below.

Pan evaporation data were obtained at Stuttgart and are shown in Table 8 and Figure 10 as monthly averages in feet per day. The radiant energy data were obtained at Little Rock and were recorded as Langleys (calories per square centimeter per day). These data were converted to evapotranspiration equivalents as feet of water per day (R_s) by multiplying Langleys by 5.712×10^{-5}. The monthly averages are shown on Figure 10. Daily precipitation was used as feet of water. "Actual" evaporation from the soil (E. soil) was determined from the daily precipitation, pan evaporation, and assumed rates of evaporation from the soil following a rain (See Table 9). Potential evaporation (pan evaporation) or the actual amount of rain, whichever was smaller, was used on the day of the rain. Following the day of rain, evaporation from the soil surface was considered significant only until 0.02 feet of water had evaporated; except for forest vegetation, where 0.01 feet was used. Columns 1 and 2 in Table 10 show how "Actual" evaporation was calculated for cotton or soybeans during 1958. Explanations of the other columns in Table 10 are given on Pages 91 and 92. The first column of each month shows the precipitation by days and the second column shows how evaporation was accounted for following the precipitation. Table 11 and Figure 10 show the "Actual" calculated evaporation rate.

Potential transpiration was considered as the difference between the potential evapotranspiration (R_s) and the calculated "actual" evaporation from the soil (E. soil). See Figures 10, 11, 12, 13, and 14. These were considered to represent the peak or potential transpiration rates under optimum conditions of soil moisture, full root development, peak stages of growth, no insects or disease, etc.

The potential transpiration values were modified to account for some of the deviation from the above optimums. The moisture use curves in Figs. 11, 12, 13, and 14 were based upon growth curve data obtained for crops in the observational study and other information. These growth curves under the potential transpiration curves represent the maximum transpiration accounting for stage of growth but under optimum conditions of soil moisture, stand of crop, insect control, etc. All of these factors except soil moisture content were considered optimum. Figure 15 and Table 12 show how the relationship between soil moisture contents in the root zones and "actual" transpiration rates were evaluated.

The available moisture content of the root zone at field capacity was determined by the available moisture content at field capacity, 0.17 feet per foot for field crops and 0.25 feet per foot for forest, and a moisture extraction pattern of 40, 30, 20, and 10 percent from each 1/4 of the root zone from the surface, respectively. In making these determinations it was estimated that 100% of the available moisture would be used by plants in the upper 1/4 of the root zone, 75% from the second 1/4, 50% from the third 1/4, and 25% from the fourth, or lowest 1/4 of the root zone. Table 13 shows the determination.

(Text continued on Page 91)

Table 8
Pan Evaporation (ft/day)

Stuttgart, Arkansas

Month	Year 1958	1959	1960	1961	1962
Jan	.0029	.0023	.0022	.0024	.0020
Feb	.0038	.0054	.0041	.0050	.0084
Mar	.0045	.0096	.0072	.0093	.0112
Apr	.0110	.0134	.0146	.0142	.0161
May	.0125	.0168	.0154	.0159	.0275
Jun	.0154	.0168	.0195	.0168	.0205
Jul	.0156	.0161	.0177	.0177	.0230
Aug	.0140	.0164	.0174	.0144	.0225
Sep	.0111	.0130	.0129	.0124	.0136
Oct	.0080	.0089	.0071	.0096	.0114
Nov	.0061	.0054	.0048	.0042	.0065
Dec	.0042	.0041	.0026	.0035	.0040

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Table 9

Evaporation Rate of Soil Water Following Rain (ft/day)

Potential Evaporation	Days			
	1	2	3	4
.001	.001 ft/day for 20 days			
.002	.002 " " 10 days			
.003	.003 " " 7 days			
.004	.004 " " 5 days			
.005	.005 " " 4 days			
.006	.006	.006	.006	.002
.007	.007	.007	.004	.002
.008	.008	.006	.004	.002
.009	.009	.005	.004	.002
.010	.010	.005	.003	.002
.011	.011	.005	.002	.002
.012	.012	.005	.002	.001
.013	.013	.006	.001	
.014	.014	.006		
.015	.015	.005		
.016	.016	.004		
.017	.017	.003		
.018	.018	.002		
.019	.019	.001		
.020	.020			
.021	.020			
.022	.020			
.023	.020			

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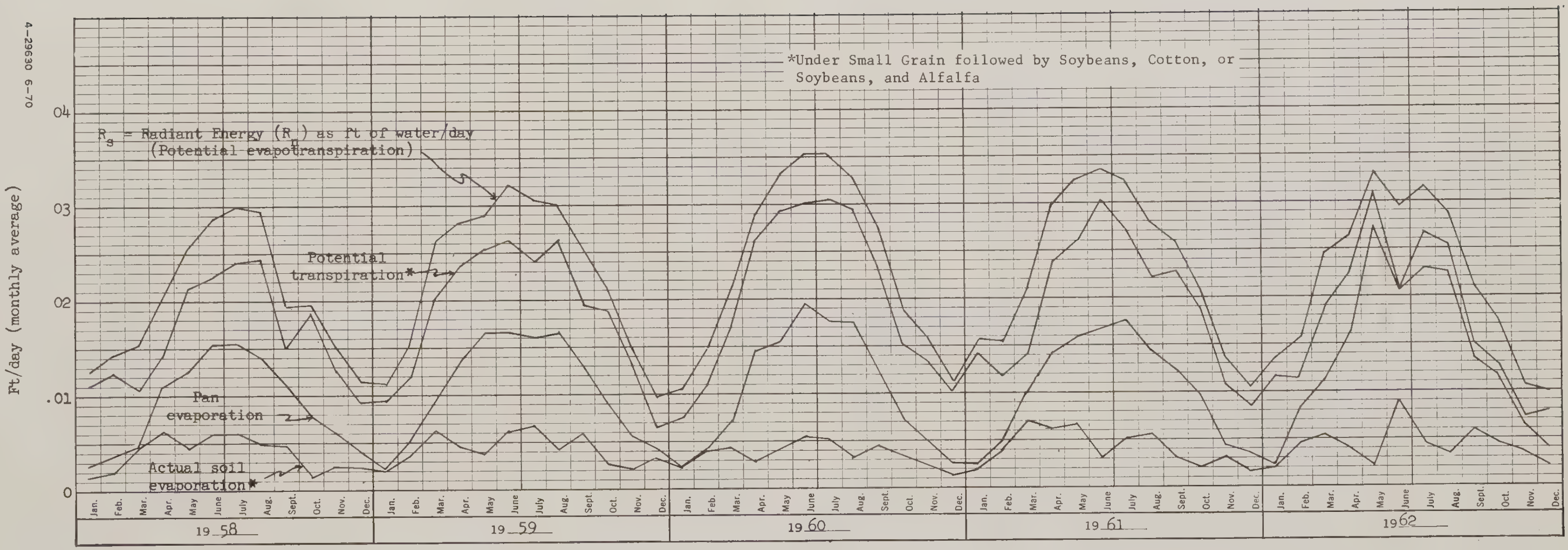

Figure 10. EVAPORATION AND TRANSPIRATION VALUES 1958–1962

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Table 10 Calculation of "A" Values for Cotton or Soybeans
1958

Jan				Feb				Mar				Apr				
Ppt.	E	Soil Water	+A	Ppt.	E	Soil Water	+A	Ppt.	E	Soil Water	+A	Ppt.	E	Soil Water	+A	Day
					.004	.285			.005	.287		.002	.007	.285		1
					.004	.281			.005	.282			.003	.282		2
					.001	.280			.002	.280		.097	.010	.300	.001	3
						.280		.002	.002	.280			.010	.290	.001	4
				.038	.004	.300	.001	.011	.005	.286			.005	.285	.001	5
				.018	.004	.300	.001	.027	.005	.300	.001		.003	.282		6
					.004	.296	.001	.055	.005	.300	.001		.002	.280		7
					.004	.292	.001	.041	.005	.300	.001			.280		8
					.004	.288			.005	.295	.001	.001	.001	.280		9
					.004	.284			.005	.290	.001	.005	.005	.280		10
		.300			.004	.280			.005	.285		.001	.001	.280		11
.008	.003	.300	.001			.280		.040	.005	.300	.001			.280		12
.067	.003	.300	.001			.280			.005	.295	.001	.002	.002	.280		13
.008	.003	.300	.001	.052	.004	.300	.001		.005	.290	.001	.051	.010	.300	.001	14
	.003	.297	.001		.004	.296	.001		.005	.285			.010	.290	.001	15
	.003	.294	.001		.004	.292	.001		.005	.280			.005	.285	.001	16
	.003	.291			.004	.288		.038	.005	.300	.001		.003	.282		17
	.003	.288			.004	.284			.005	.295	.001		.002	.280		18
.011	.003	.296			.004	.280			.005	.290	.001	.016	.010	.286		19
.257	.003	.300	.001			.280			.005	.285		.087	.010	.300	.001	20
	.003	.297	.001			.280			.005	.280		.018	.010	.300	.001	21
	.003	.294	.001			.280		.003	.003	.280			.010	.290	.001	22
	.003	.291				.280		.087	.005	.300	.001		.005	.285	.001	23
	.003	.288				.280		.007	.005	.300	.001	.002	.005	.282		24
	.003	.285				.280		.007	.005	.300	.001	.052	.010	.300	.001	25
	.003	.282		.052	.004	.300	.001	.011	.005	.300	.001	.127	.010	.300	.001	26
	.002	.280			.004	.296	.001		.005	.295	.001	.033	.010	.300	.001	27
		.280			.004	.292	.001		.005	.290	.001	.146	.010	.300	.001	28
		.280		-	-	-	-	.021	.005	.300	.001	.038	.010	.300	.001	29
.015	.003	.292							.005	.295	.001	.006	.010	.296	.001	30
	.003	.289							.005	.290	.001	-	-	-	-	31
Total			.008				.010				.020				.016	
Average			.0003				.0003				.0006				.0005	
A with no water table in root zone			.0003				.0003				.0006				.0005	
A with no excess water table in root zone			.0003				.0003				.0006				.0005	

Table 10 Calculation of "A" Values for Cotton or Soybeans
1958 (continued)

Day	May Ppt.	May E	May Max. T	May Act. T	May Soil Water	May +A	Jun Ppt.	Jun E	Jun Max. T	Jun Act. T	Jun Soil Water	Jun +A
1	.116	.012			.300	.001			.003	.003	.257	
2	.278	.012			.300	.001			.003	.003	.254	
3	.004	.012			.292	.001			.003	.003	.251	
4	.087	.012			.300	.001			.004	.004	.247	
5		.012			.288	.001			.004	.004	.243	
6		.005			.283	.001			.004	.004	.239	
7		.002			.281				.005	.005	.234	
8	.002	.003			.280				.005	.005	.229	
9	.115	.012			.300	.001			.005	.005	.224	
10	.002	.012			.290	.001			.006	.006	.218	
11		.007			.283	.001	.115	.014	.006	.006	.300	.001
12		.002			.281			.014	.006	.006	.280	.001
13		.001			.280			.006	.007	.007	.267	.001
14					.280				.007	.007	.260	
15					.280		.018	.014	.007	.007	.257	
16					.280		.049	.014	.008	.008	.284	
17					.280			.014	.008	.008	.262	
18			.001	.001	.279			.006	.008	.008	.248	
19	.050	.012	.001	.001	.300	.001	.026	.014	.009	.009	.251	
20		.012	.001	.001	.287	.001	.013	.014	.009	.009	.241	
21		.005	.001	.001	.281	.001	.060	.014	.009	.009	.278	
22		.002	.001	.001	.278			.014	.010	.010	.254	
23		.001	.001	.001	.276			.006	.010	.010	.238	
24			.001	.001	.275				.011	.011	.227	
25			.002	.002	.273		.316	.014	.011	.011	.300	.001
26			.002	.002	.271		.002	.014	.012	.012	.276	.001
27			.002	.002	.269			.008	.012	.012	.256	.001
28			.002	.002	.267				.013	.013	.243	
29			.002	.002	.265				.013	.013	.230	
30			.002	.002	.263				.014	.014	.216	
31			.003	.003	.260		-	-	-	-	-	-
Total			.022	.022		.012			.232	.232		.006
Average			.0007	.0007		.0004			.0077	.0077		.0002
A with no water table in root zone						.0004						.0002
A with no excess water table in root zone						.0004						.0002

Day	Jul Ppt.	Jul E	Jul Max. T	Jul Act. T	Jul Soil Water	Jul +A	Aug Ppt.	Aug E	Aug Max. T	Aug Act. T	Aug Soil Water	Aug +A
1			.014	.013	.203				.024	.002	.030	
2			.014	.013	.190		.024	.014	.024	.002	.038	
3			.015	.013	.177		.043	.014	.024	.002	.065	
4			.015	.012	.165			.014	.024	.005	.046	
5	.003	.003	.016	.012	.153			.006	.024	.003	.037	
6	.092	.016	.016	.011	.218				.024	.002	.035	
7	.073	.016	.017	.016	.259				.024	.002	.033	
8		.016	.017	.017	.226		.045	.014	.024	.002	.062	
9		.004	.018	.017	.205		.002	.014	.024	.005	.045	
10			.018	.016	.189			.008	.024	.003	.034	
11			.019	.016	.173				.024	.002	.032	
12	.026	.016	.019	.015	.168		.015	.114	.023	.002	.031	
13	.002	.012	.020	.015	.143			.001	.023	.002	.028	
14			.020	.013	.130				.023	.002	.026	
15			.021	.012	.118				.023	.001	.025	
16			.021	.011	.107				.023	.001	.024	
17			.022	.010	.097		.168	.014	.022	.001	.177	
18			.022	.009	.088			.014	.022	.018	.145	
19			.022	.008	.080			.006	.022	.015	.124	
20	.010	.010	.022	.007	.073				.022	.012	.112	
21	.026	.016	.022	.006	.077				.021	.010	.102	
22		.010	.022	.006	.061		.004	.004	.021	.009	.093	
23	.005	.005	.023	.004	.057		.015	.014	.021	.008	.086	
24			.023	.004	.053			.001	.021	.007	.078	
25	.017	.016	.023	.004	.050				.020	.006	.072	
26	.008	.009	.023	.003	.046				.020	.005	.067	
27			.023	.003	.043				.020	.005	.062	
28	.006	.006	.023	.003	.040				.020	.004	.058	
29	.029	.016	.023	.002	.051				.020	.003	.055	
30		.013	.023	.004	.034				.020	.003	.052	
31			.024	.002	.032				.019	.003	.049	
Total			.620	.297		0			.690	.147		0
Average			.0200	.0096		0			.0223	.0047		0
A with no water table in root zone						0						0
A with no excess water table in root zone				-.0104						-.0176		

Table 10 **Calculation of "A" Values for Cotton or Soybeans**

1958 (continued)

Sheet 3 of 3

Sep						Oct						Nov						Dec				
Ppt.	E	Max. T	Act. T	Soil Water	+ A	Ppt.	E	Max. T	Act. T	Soil Water	+ A	Ppt.	E	Max. T	Act. T	Soil Water	+ A	Ppt.	E	Soil Water	+ A	Day
.005	.005	.019	.003	.046			.008	.009	.009	.249				.002	.001	.112			.004	.284		1
		.019	.003	.043			.006	.009	.009	.234				.002	.001	.111		.010	.004	.290		2
		.019	.002	.041			.004	.009	.009	.221				.002	.001	.110			.004	.286		3
		.018	.002	.039			.002	.008	.008	.211				.002	.001	.109			.004	.282		4
		.018	.002	.037				.008	.008	.203				.001	.001	.108			.002	.280		5
		.018	.002	.035				.008	.008	.195				.001	.001	.107				.280		6
		.017	.002	.033				.007	.006	.189				.001	.001	.106				.280		7
		.017	.002	.031				.007	.006	.183		.001	.001	.001	.001	.105				.280		8
		.017	.001	.030				.007	.006	.177				.001	.001	.104				.280		9
.112	.011	.016	.001	.130		.003	.003	.006	.005	.172				.000		.104				.280		10
.017	.011	.016	.009	.127				.006	.005	.167						.104				.280		11
	.011	.016	.009	.107				.006	.005	.162						.104		.032	.004	.300	.001	12
	.005	.015	.007	.095				.005	.004	.158						.104		.018	.004	.300	.001	13
	.002	.015	.006	.087				.005	.004	.154		.297	.006			.300	.001		.004	.296	.001	14
.005	.007	.015	.005	.080				.005	.004	.150			.006			.294	.001		.004	.292	.001	15
.118	.011	.014	.005	.182				.004	.003	.147			.006			.288	.001		.004	.288		16
.007	.011	.014	.012	.166				.004	.003	.144		.065	.006			.300	.001		.004	.284		17
	.011	.014	.011	.144				.004	.003	.141		.009	.006			.300	.001		.004	.280		18
.197	.011	.013	.009	.300	.001			.004	.003	.138			.006			.294	.001			.280		19
.025	.011	.013	.013	.300	.001			.004	.003	.135			.006			.288	.001			.280		20
	.011	.013	.013	.276	.001	.003	.003	.004	.003	.132			.006			.282				.280		21
	.005	.012	.012	.259		.014	.008	.003	.002	.136			.002			.280		.009	.004	.285		22
	.002	.012	.012	.245			.006	.003	.002	.128						.280			.004	.281		23
	.002	.012	.012	.231				.003	.002	.126						.280			.001	.280		24
		.011	.011	.220				.003	.002	.124						.280				.280		25
		.011	.011	.209				.003	.002	.122		.003	.003			.280		.001	.001	.280		26
		.011	.010	.199				.003	.002	.120		.025	.006			.299		.019	.004	.295		27
		.010	.009	.190				.003	.002	.118		.045	.006			.300	.001		.004	.291		28
		.010	.009	.181				.003	.002	.116			.006			.294	.001		.004	.287		29
.104	.011	.009	.008	.266				.003	.002	.114			.006			.288	.001		.004	.283		30
-	-	-	-	-	-	.005	.005	.002	.001	.113		-	-	-	-	-	-	.016	.004	.295		31
Total		.434	.213		.003			.158	.133		0			.013	.009		.010				.004	
Average		.0145	.0071		.0001			.0051	.0043		0			.0004	.0003		.0003				.0001	
A with no water table in root zone					.0001						0						.0003				.0001	
A with no excess water table in root zone -.0073									-.0008						.0002					.0001		

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Table 11

Actual Evaporation for Cotton, Small Grain, Soybeans, Alfalfa (ft/day)

Month	1958	1959	1960	1961	1962
Jan	.0015	.0020	.0030	.0018	.0020
Feb	.0020	.0037	.0040	.0039	.0046
Mar	.0047	.0062	.0043	.0070	.0053
Apr	.0061	.0044	.0029	.0062	.0041
May	.0044	.0038	.0040	.0067	.0022
Jun	.0060	.0061	.0053	.0031	.0091
Jul	.0059	.0068	.0051	.0051	.0047
Aug	.0049	.0041	.0032	.0056	.0034
Sep	.0046	.0059	.0045	.0031	.0059
Oct	.0014	.0027	.0035	.0021	.0044
Nov	.0026	.0021	.0025	.0031	.0036
Dec	.0024	.0032	.0014	.0018	.0021

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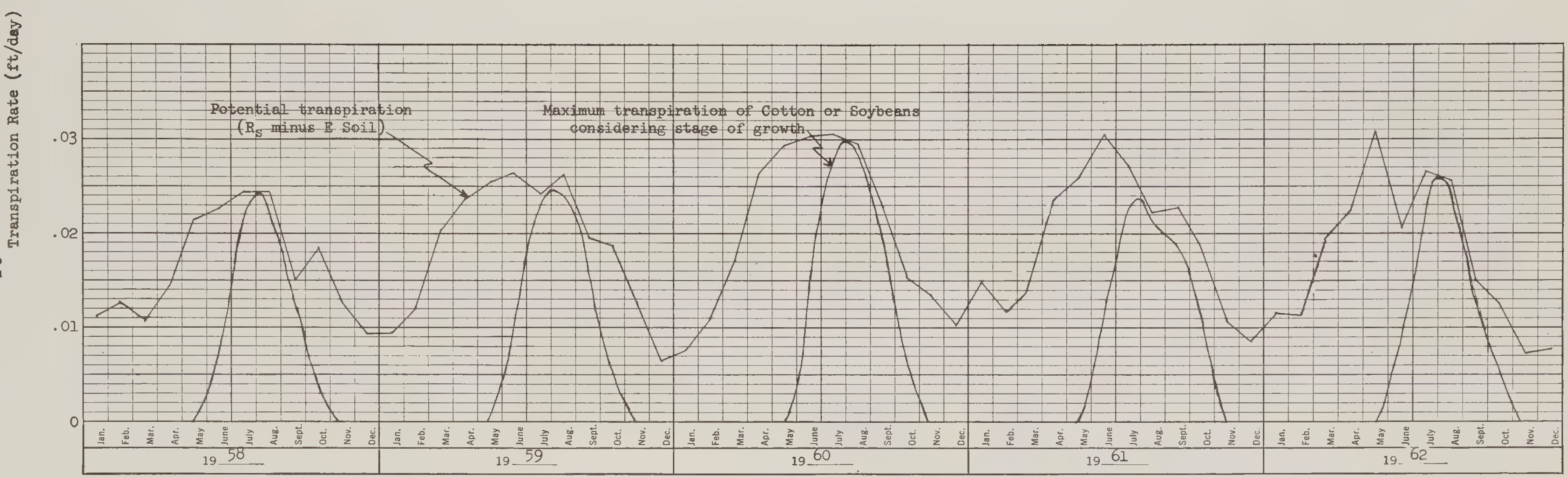

Figure 11. POTENTIAL TRANSPIRATION AND MAXIMUM TRANSPIRATION RATES FOR COTTON OR SOYBEANS CONSIDERING STAGE OF GROWTH

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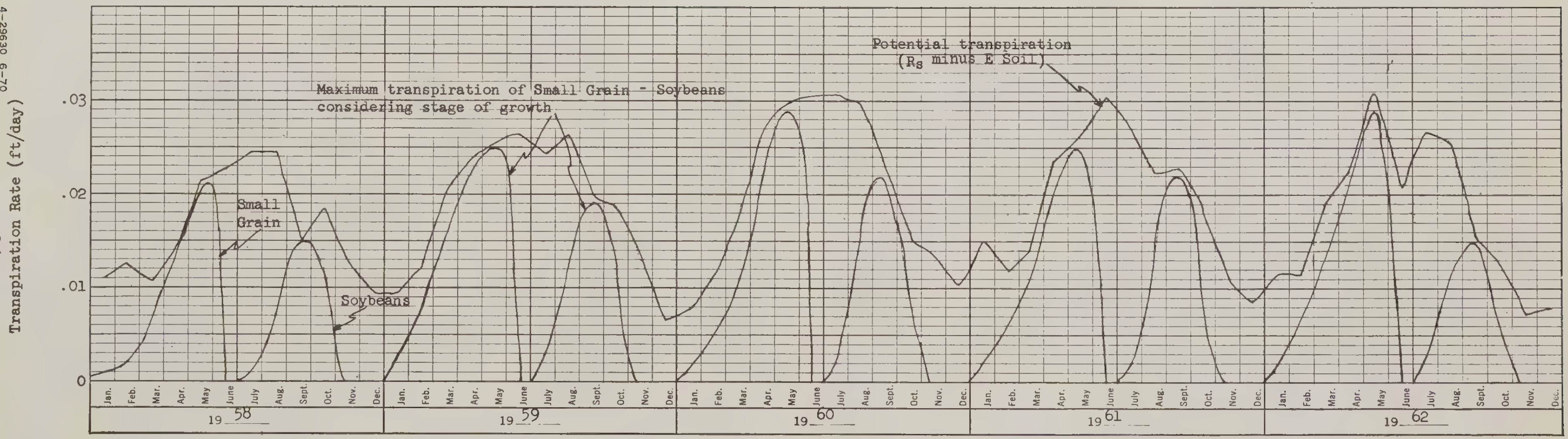

Figure 12. POTENTIAL TRANSPIRATION AND MAXIMUM TRANSPIRATION RATES FOR SMALL GRAIN FOLLOWED BY SOYBEANS CONSIDERING STAGE OF GROWTH

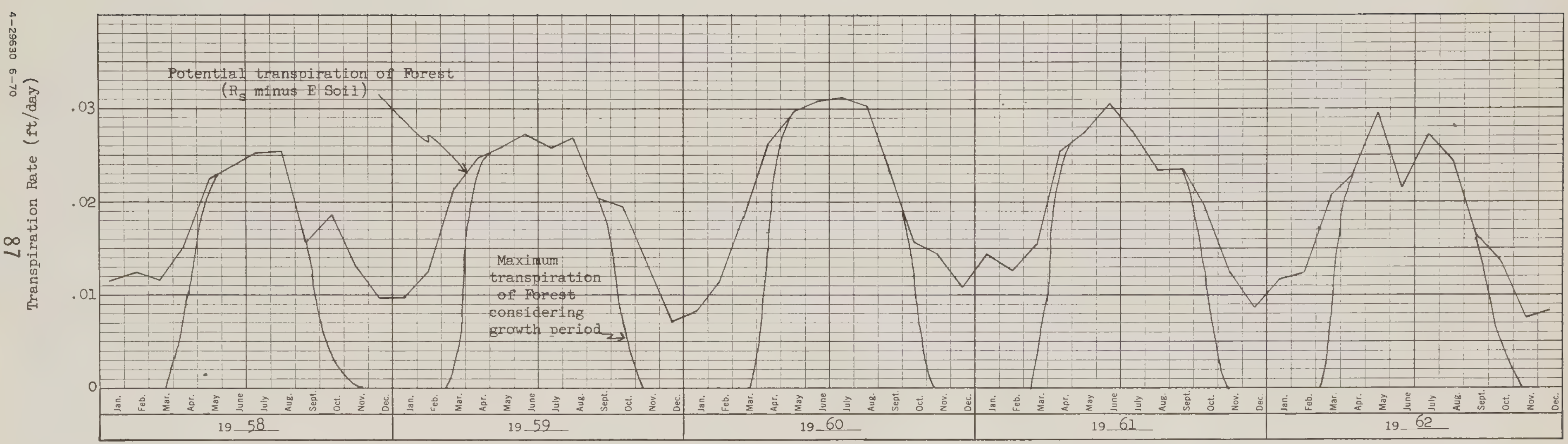

Figure 13. POTENTIAL TRANSPIRATION AND MAXIMUM TRANSPIRATION RATES FOR FOREST VEGETATION CONSIDERING GROWTH PERIOD

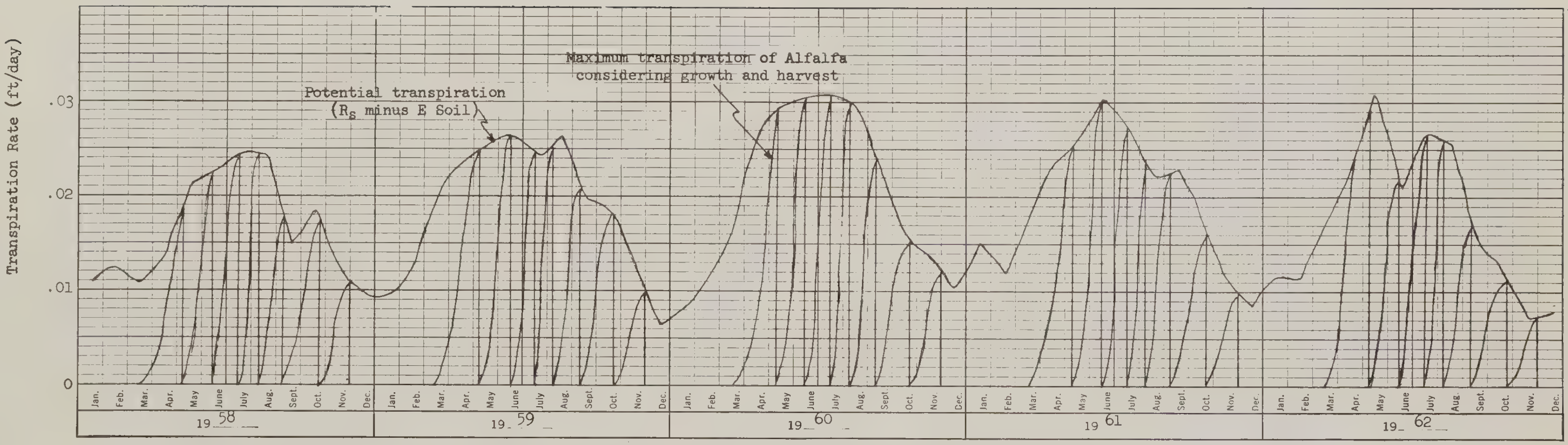

Figure 14. POTENTIAL TRANSPIRATION AND MAXIMUM TRANSPIRATION RATES FOR ALFALFA CONSIDERING GROWTH PERIOD AND HARVESTS

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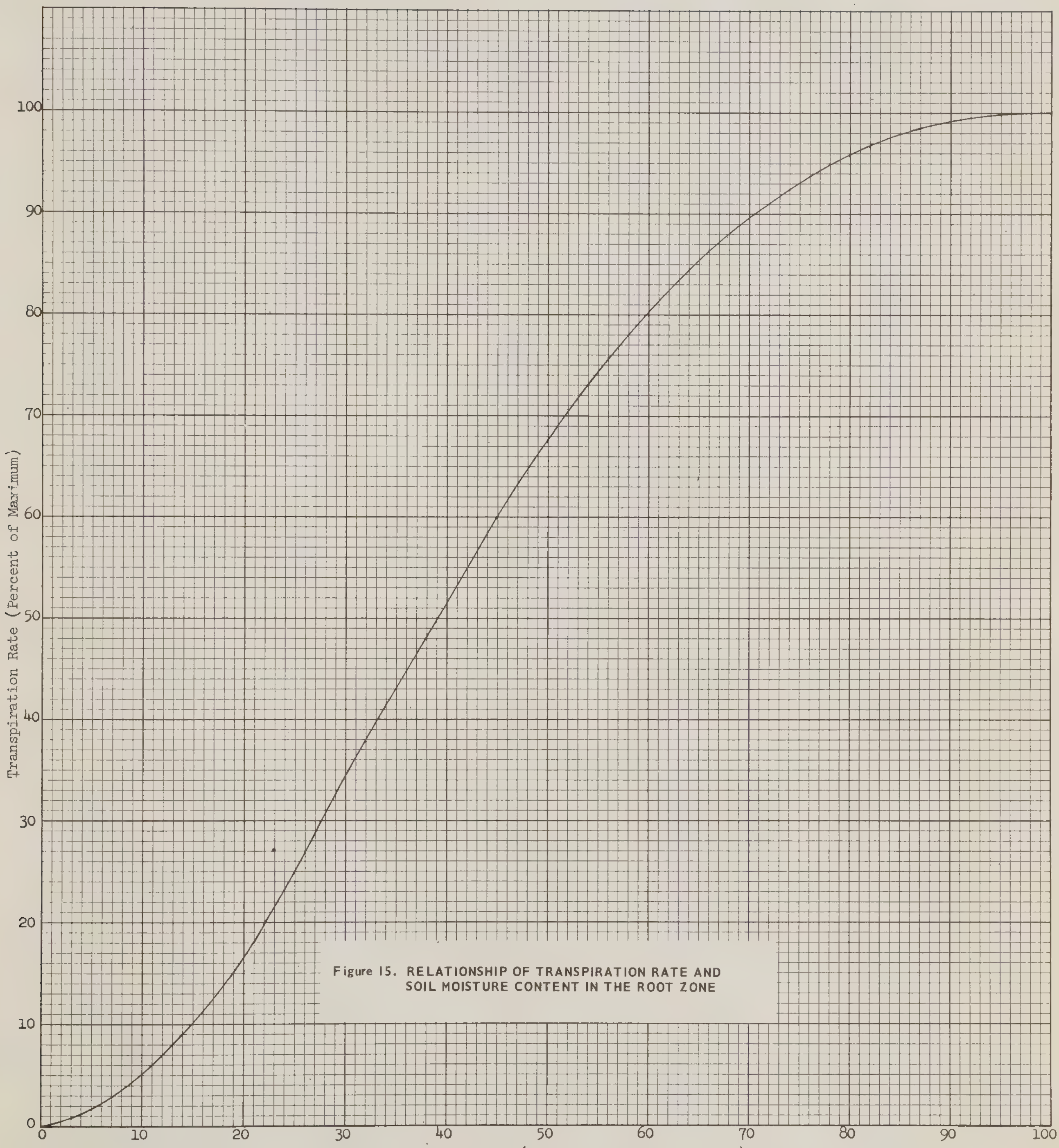

Figure 15. RELATIONSHIP OF TRANSPIRATION RATE AND SOIL MOISTURE CONTENT IN THE ROOT ZONE

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Table 12 The Relation of Soil Moisture Content to Maximum and Actual Transpiration of Small Grain, Cotton and Soybeans

Max. Trans.	Actual Transpiration																														
		.001	.002	.003	.004	.005	.006	.007	.008	.009	.010	.011	.012	.013	.014	.015	.016	.017	.018	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030
.030	0	.024	.034	.043	.053	.060	.065	.072	.077	.082	.089	.094	.099	.103	.110	.118	.122	.130	.134	.139	.148	.156	.163	.170	.180	.189	.202	.211	.225	.248	.300
.029	0	.024	.036	.045	.053	.060	.067	.072	.079	.084	.089	.096	.101	.108	.112	.120	.124	.132	.140	.146	.154	.162	.169	.178	.188	.199	.211	.225	.245	.300	
.028	0	.024	.036	.045	.055	.063	.070	.075	.079	.086	.091	.099	.103	.110	.118	.122	.130	.136	.144	.151	.158	.169	.175	.184	.196	.208	.225	.243	.300		
.027	0	.024	.039	.048	.058	.063	.070	.077	.082	.089	.094	.101	.106	.112	.120	.127	.134	.139	.148	.156	.166	.172	.184	.194	.208	.220	.240	.300			
.026	0	.024	.039	.048	.058	.065	.072	.077	.084	.091	.096	.103	.110	.118	.122	.132	.139	.146	.156	.163	.170	.182	.194	.206	.220	.240	.300				
.025	0	.024	.039	.048	.058	.065	.072	.079	.086	.094	.099	.106	.112	.120	.127	.134	.144	.151	.162	.170	.180	.192	.204	.218	.240	.300					
.024	0	.026	.041	.050	.060	.067	.075	.082	.089	.096	.101	.110	.118	.124	.132	.140	.148	.158	.169	.178	.189	.202	.218	.240	.300						
.023	0	.026	.041	.050	.063	.070	.077	.084	.091	.099	.106	.112	.120	.130	.139	.146	.156	.168	.175	.188	.202	.218	.240	.300							
.022	0	.028	.043	.053	.063	.070	.079	.086	.094	.101	.108	.118	.124	.134	.144	.154	.163	.172	.184	.196	.216	.240	.300								
.021	0	.028	.043	.055	.063	.072	.079	.089	.096	.103	.112	.120	.130	.139	.148	.158	.170	.182	.196	.213	.237	.300									
.020	0	.028	.043	.058	.065	.075	.082	.091	.099	.108	.118	.124	.134	.146	.156	.169	.180	.194	.211	.237	.300										
.019	0	.028	.045	.060	.070	.077	.086	.094	.103	.112	.122	.132	.142	.154	.166	.178	.192	.208	.235	.300											
.018	0	.031	.048	.060	.072	.079	.089	.096	.108	.118	.127	.139	.148	.162	.172	.189	.206	.230	.300												
.017	0	.031	.048	.063	.072	.082	.091	.101	.112	.122	.134	.146	.158	.170	.188	.204	.230	.300													
.016	0	.034	.050	.063	.075	.086	.096	.106	.118	.130	.139	.154	.169	.182	.202	.230	.300														
.015	0	.036	.053	.065	.077	.089	.099	.110	.122	.134	.148	.163	.180	.199	.225	.300															
.014	0	.036	.055	.070	.079	.091	.103	.118	.130	.144	.158	.175	.196	.225	.300																
.013	0	.039	.058	.072	.084	.096	.110	.122	.139	.156	.170	.194	.220	.300																	
.012	0	.041	.060	.075	.089	.101	.118	.132	.148	.169	.189	.218	.300																		
.011	0	.043	.063	.079	.094	.108	.124	.144	.163	.184	.216	.300																			
.010	0	.043	.065	.082	.099	.118	.134	.156	.180	.211	.300																				
.009	0	.048	.072	.089	.108	.127	.148	.172	.206	.300																					
.008	0	.050	.075	.096	.118	.139	.169	.202	.300																						
.007	0	.055	.079	.103	.130	.158	.196	.300																							
.006	0	.060	.089	.118	.148	.189	.300																								
.005	0	.065	.099	.134	.180	.300																									
.004	0	.075	.118	.169	.300																										
.003	0	.089	.148	.300																											
.002	0	.118	.300																												

Soil Moisture Content (ft)

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Table 13 Moisture Extraction Pattern

Extraction Pattern in root zone Percent	Depth Feet	Available Water Feet
	Small Grain, Cotton, and Soybeans	
40	0.75	0.12
30	0.75	0.09
20	0.75	0.06
10	0.75	0.03
100	3.00	0.30
	Alfalfa	
40	1.25	0.21
30	1.25	0.16
20	1.25	0.10
10	1.25	0.05
100	5.00	0.52
	Forest	
40	2.0	0.50
30	2.0	0.38
20	2.0	0.25
10	2.0	0.12
100	8.0	1.25

The values for available soil moisture in the root zone that were used in the calculations of "A" values were 0.30 feet for small grain, cotton, and soybeans; 0.52 feet for alfalfa; and 1.25 feet for forest vegetation.

An infiltration rate of water to the water table equal to the K value (permeability rate) was used as a positive A value (accretion rate) on the day and 2 days following the day when the soil moisture contents reached the above values. All precipitation in excess of this was considered as a runoff and no account was made for surface ponding.

Table 10, Pages 81 to 83 , shows how the A values were calculated for cotton or soybeans for 1958. This table includes precipitation, evaporation, maximum transpiration, "actual" transpiration, soil moisture content, and positive A values on a daily water balance type computation. At the time of the first rain in 1958 it was assumed that the soil was at field capacity for cotton, soybeans, alfalfa, and forest; and on January 1, 1958 for small grain. To determine soil moisture content, the evaporation and transpiration (where present) were subtracted from the rainfall

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and the remaining rainfall was added to the soil moisture content until the field capacity was reached. When only transpiration was occurring, it was subtracted from the soil moisture content and the next day's "actual" transpiration rate was determined from tables like Table 12, Page 90 .

The difference between the maximum transpiration and the "actual" transpiration represents the negative part of the net A value. The sum of the average monthly positive A value (infiltration) and the negative A value gives the net positive or the negative A value used to calculate the water table from the piezometric surface.

The A value will be zero or positive and equal to the monthly average infiltration, if the water table is below the root zone of crops (when evapotranspiration does not involve water from the water table).

Tables 14 and 15 give the class and range of "actual" A values and Tables 16, 17, and 18 give the A values that were used to calculate the water table from the piezometric surface for soil permeabilities of 0.001 feet per day and 0.01 feet per day.

Figure 16 shows the assumed depths where the root zones and water table depths would be significant and the depth at which the water table was considered to be in the root zone in the calculation of the water table from the piezometric surface.

Graphs of the equation used to calculate water table hydrographs from piezometric hydrographs (Page 99& 100) were made for various values of A, h_p, and K for any values of h and t. Figures 17 and 18 are included as examples and are the graphs for soils with a K value of 0.001 feet per day and A values of +0.0006 feet per day for rising and falling water tables. The horizontal scale for the falling water table is given as a rate of fall in days per foot and on the graphs for rising water tables it is days to represent t_1 and t_2. The vertical scale is in feet for h_1 and h_2. The lines in the body of the graphs are for different h_p values. Figure 19 shows a graph of total evaporation for crops under conditions of no water table in the root zone for calendar years 1958 through 1962.

Not all of the piezometric holes were logged, so the map of the contours of the elevation base of the fine-textured material and its permeability (Figure 9, Page 76) was used as the basis of the h, h_p, and K values. When the h_p went below the base of the fine-textured material, it was calculated as zero and not a negative h_p. If both the piezometric surface (h_p) and water table (h) fell below the base of the fine-textured material, then the water table was assumed to be the same as the piezometric surface.

Since it was not known what the value for h_1 was at the beginning of the study period (January 1, 1958) it was assumed to be the average piezometric surface for the five year period. Thus, some of the water tables

(Text continued on Page 102)

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Table 14
Class and Range of A Values for Soils
with Permeability of 0.001 Feet per Day

Class (ft/day)	Range (ft/day)
A = -.030	<-.0149
A = -.020	-.0150 to -.0249
A = -.010	-.0050 to -.0149
A = -.003	-.0005 to -.0049
A = 0	-.0004 to +.0001
A = +.0003	+.0002 to +.0004
A = +.0006	+.0005 to +.0007

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Table 15
Class and Range of A Values for Soils
with Permeability of 0.01 Feet per Day

Class	Range
-.0300	<-.0250
-.0200	-.0249 to -.0150
-.0100	-.0149 to -.0075
-.0050	-.0074 to -.0040
-.0025	-.0039 to -.0010
0	-.0009 to +.0008
.0015	+.0009 to +.0024
.0050	+.0024 to +.0070^{+}

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Table 16 A Values for Calculating Water Table from Piezometric Surface Where K = .001

		Cotton or Soybeans					Small Grain - Soybeans					Alfalfa					Forest				
Month	Water Table	1958	1959	1960	1961	1962	1958	1959	1960	1961	1962	1958	1959	1960	1961	1962	1958	1959	1960	1961	1962
Jan	w/o	.0003	.0003	.0006	.0003	.0006	.0003	.0003	.0003	.0003	.0006	.0003	.0003	.0006	.0003	.0006	.0003	0	.0003	0	.0003
	w	.0003	.0003	.0006	.0003	.0006	.0003	.0003	.0003	.0003	.0006	.0003	.0003	.0006	.0003	.0006	.0003	0	.0003	0	.0003
Feb	w/o	.0003	.0003	.0006	.0003	.0003	.0003	0	.0003	0	.0003	.0003	.0003	.0006	.0003	.0003	.0003	.0003	.0006	0	.0003
	w	.0003	.0003	.0006	.0003	.0003	.0003	0	.0003	0	.0003	.0003	.0003	.0006	.0003	.0003	.0003	.0003	.0006	0	.0003
Mar	w/o	.0006	.0006	.0006	.0006	.0003	.0003	0	.0003	.0003	0	.0006	.0003	.0003	.0006	.0003	.0006	.0003	.0003	.0006	.0003
	w	.0006	.0006	.0006	.0006	.0003	.0003	-.0100	-.0030	.0003	-.0030	.0006	.0003	.0003	.0006	.0003	.0006	.0003	.0003	.0006	.0003
Apr	w/o	.0006	.0003	0	.0003	.0003	0	0	0	0	0	.0003	0	0	.0003	0	.0003	0	0	0	0
	w	.0006	.0003	0	.0003	.0003	-.0030	-.0200	-.0200	-.0100	-.0100	.0003	-.0030	-.0030	-.0100	-.0100	.0003	-.0030	-.0030	-.0030	-.0030
May	w/o	.0003	0	.0003	.0003	0	.0003	0	0	0	0	.0003	0	0	.0003	0	.0003	0	0	0	0
	w	.0003	0	.0003	.0003	0	-.0100	-.0300	-.0200	-.0100	-.0200	.0003	-.0100	-.0030	-.0100	-.0100	0	-.0100	-.0100	-.0100	-.0100
Jun	w/o	.0003	0	0	0	.0003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	.0003	0	-.0030	-.0030		-.0030	-.0030	-.0100	-.0030	-.0030	-.0030	-.0100	-.0100	-.0030	-.0100	-.0100	-.0200	-.0200	-.0200	-.0100
Jul	w/o	0	0	0	0	0	0	.0003	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	-.0100	-.0100	-.0200	-.0200	-.0100	0	.0003	0	-.0030	0	-.0030	-.0030	-.0030	-.0100	-.0100	-.0100	-.0100	-.0200	-.0200	-.0200
Aug	w/o	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	-.0200	-.0200	-.0300	-.0200	-.0200	0	-.0030	-.0030	-.0100	-.0030	-.0030	-.0030	-.0100	-.0100	-.0100	-.0200	-.0200	-.0200	-.0200	-.0200
Sep	w/o	0	0	.0003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	-.0100	-.0100	-.0100	-.0200	-.0100	-.0030	-.0100	-.0100	-.0200	-.0100	-.0030	-.0030	-.0030	-.0100	-.0030	-.0100	-.0100	-.0200	-.0200	-.0100
Oct	w/o	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	-.0030	0	-.0030	-.0100	-.0030	-.0030	-.0030	-.0030	-.0100	-.0100	-.0030	-.0030	-.0030	-.0100	-.0030	-.0030	-.0030	-.0100	-.0100	-.0030
Nov	w/o	.0003	0	0	0	0	.0003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	.0003	0	0	0	0	0	0	0	-.0030	0	-.0030	-.0030	-.0030	-.0100	-.0030	0	0	0	0	0
Dec	w/o	0	.0003	.0003	.0006	0	0	.0003	.0003	.0006	0	0	.0003	0	.0003	0	0	0	0	0	0
	w	0	.0003	.0003	.0006	0	0	.0003	.0003	.0006	0	0	.0003	0	.0003	0	0	0	0	0	0

w/o - No water table in the root zone.
w - Water table in the root zone, but not in excess amount nor depth to be damaging to root growth.

Table 17
A Values for Calculating Water Table from Piezometric Surfaces where K = 0.001 and Under Fallow Conditions

Month	Year				
	1958	1959	1960	1961	1962
January	.0003	.0003	.0006	.0003	.0006
February	.0003	.0003	.0006	.0003	.0003
March	.0006	.0006	.0006	.0006	.0003
April	.0006	.0003	0	.0003	.0003
May	.0003	0	.0003	.0006	0
June	.0003	.0003	.0003	0	.0006
July	0	.0003	.0003	.0003	.0003
August	.0003	.0003	.0003	.0003	0
September	.0003	.0003	.0003	.0003	.0003
October	0	.0003	.0003	0	.0003
November	.0003	.0003	.0003	.0003	.0003
December	0	.0003	.0003	.0006	.0003

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Table 18 A Values for Calculating Water Table from Piezometric Surface Where K = .01 (ft/day)

		Small Grain - Soybeans					Alfalfa					Cotton or Soybeans					Forest Vegetation				
Month	Water Table	1958	1959	1960	1961	1962	1958	1959	1960	1961	1962	1958	1959	1960	1961	1962	1958	1959	1960	1961	1962
Jan	w/o	.0015	.0050	.0050	.0050	.0050	.0015	.0050	.0050	.0015	.0050	.0015	.0050	.0050	.0050	.0050	.0050	0	.0050	0	.0050
	w	.0015	.0050	.0050	.0050	.0050	.0015	.0050	.0050	.0015	.0050	.0015	.0050	.0050	.0050	.0050	.0050	0	.0050	0	.0050
Feb	w/o	.0015	.0015	.0015	.0015	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	0	.0050
	w	.0015	.0015	.0015	.0015	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	0	.0050
Mar	w/o	.0015	0	.0015	.0015	0	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0015
	w	.0015	-.0050	.0015	.0015	-.0025	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0050	.0015
Apr	w/o	.0015	0	0	.0015	0	.0050	.0015	0	.0050	0	.0050	.0050	0	.0050	.0050	.0050	0	0	0	0
	w	-.0025	-.0200	-.0200	-.0050	-.0100	.0050	-.0025	-.0025	.0015	-.0050	.0050	.0050	0	.0050	.0050	.0050	-.0025	0	0	-.0025
May	w/o	.0015	0	0	0	0	.0050	0	0	0	0	.0050	.0015	.0050	.0050	.0015	0	0	0	0	0
	w	-.0050	-.0200	-.0200	-.0100	-.0200	.0050	-.0050	-.0025	-.0025	-.0100	.0050	.0015	.0050	.0050	.0015	0	-.0100	-.0100	-.0050	-.0100
Jun	w/o	.0015	0	.0015	0	0	.0015	0	.0015	0	0	.0015	.0015	.0015	0	.0015	0	0	0	0	0
	w	-.0025	-.0050	-.0050	-.0050	-.0025	-.0025	-.0050	-.0050	-.0100	-.0050	.0015	0	-.0025	-.0025	-.0025	-.0100	-.0200	-.0200	-.0200	-.0100
Jul	w/o	.0015	.0050	.0015	0	.0015	0	0	0	0	0	0	.0015	0	0	0	0	0	0	0	0
	w	.0015	.0050	.0015	-.0025	.0015	-.0025	-.0025	-.0050	-.0100	-.0050	-.0100	-.0050	-.0200	-.0200	-.0100	-.0100	-.0100	-.0200	-.0200	-.0200
Aug	w/o	.0015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	w	0	-.0025	-.0050	-.0100	-.0050	-.0050	-.0025	-.0100	-.0100	-.0100	-.0200	-.0200	-.0300	-.0200	-.0200	-.0200	-.0200	-.0200	-.0200	-.0200
Sep	w/o	.0015	0	.0015	0	0	0	0	.0015	0	0	0	0	.0015	0	0	0	0	0	0	0
	w	-.0025	-.0100	-.0100	-.0200	-.0100	-.0025	-.0025	-.0050	-.0050	-.0050	-.0050	-.0050	-.0100	-.0200	-.0100	-.0100	-.0100	-.0200	-.0200	-.0100
Oct	w/o	0	0	0	0	0	0	0	.0015	0	0	0	0	0	0	0	0	0	0	0	0
	w	-.0025	-.0050	-.0025	-.0100	-.0050	-.0025	0	0	-.0100	-.0025	0	0	0	-.0100	-.0025	-.0025	-.0025	-.0050	-.0100	-.0025
Nov	w/o	.0050	0	0	0	0	0	0	0	0	0	.0050	.0015	0	.0015	0	0	0	0	0	0
	w	.0015	0	0	0	0	0	-.0025	-.0025	-.0025	-.0025	.0050	.0015	0	0	0	0	0	0	0	0
Dec	w/o	.0015	.0050	.0015	.0050	0	0	.0050	0	.0050	0	.0015	.0050	.0050	.0050	0	0	0	0	0	0
	w	.0015	.0050	.0015	.0050	0	0	.0050	0	.0050	0	.0015	.0050	.0050	.0050	0	0	0	0	0	0

w/o - No water table in the root zone.
w - Water table in the root zone, but not in excess amount nor depth to be damaging to root growth.

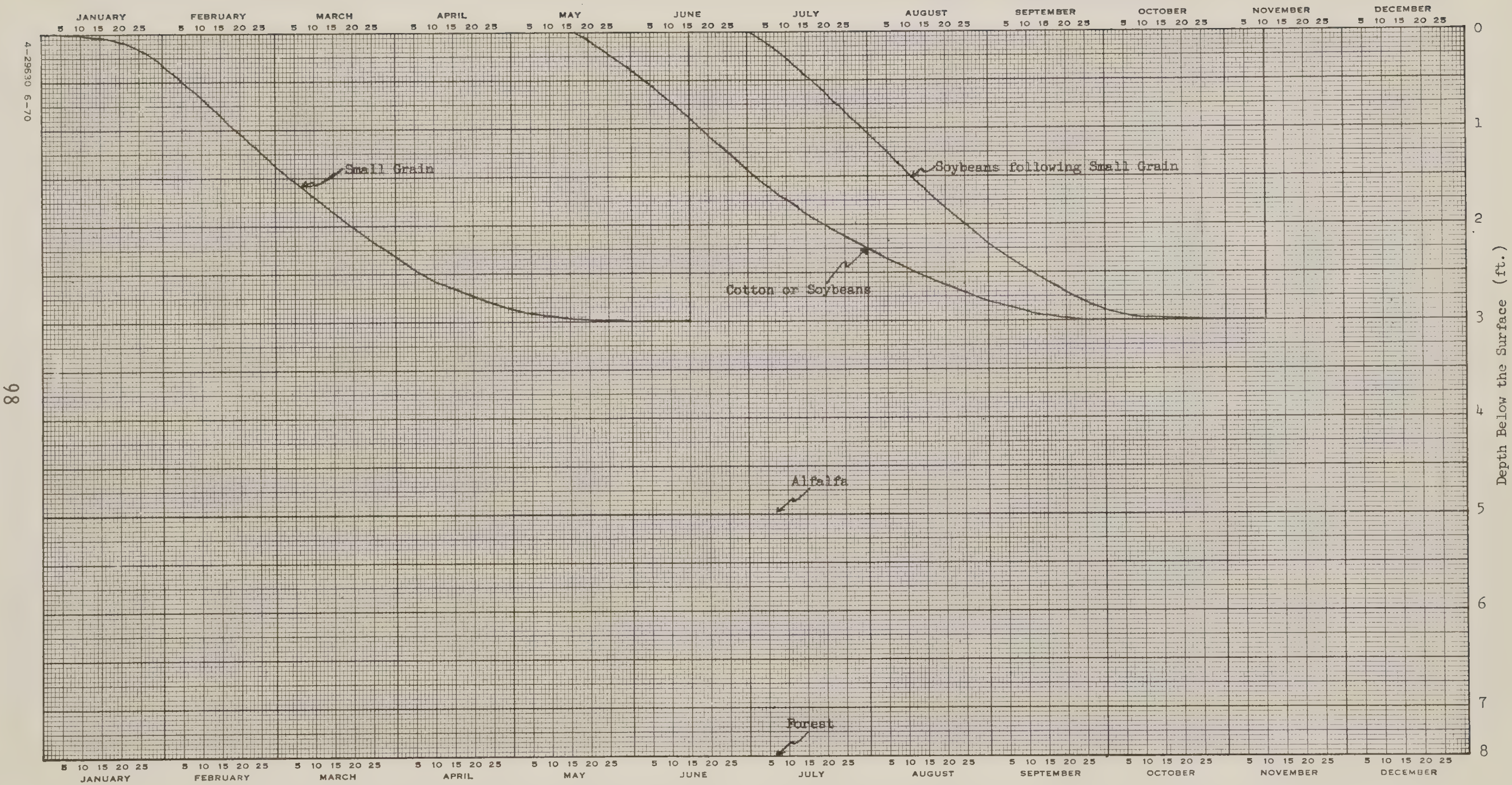

Figure 16. ROOT PENETRATION FOR DETERMINING A VALUE FROM WATER TABLE DEPTH

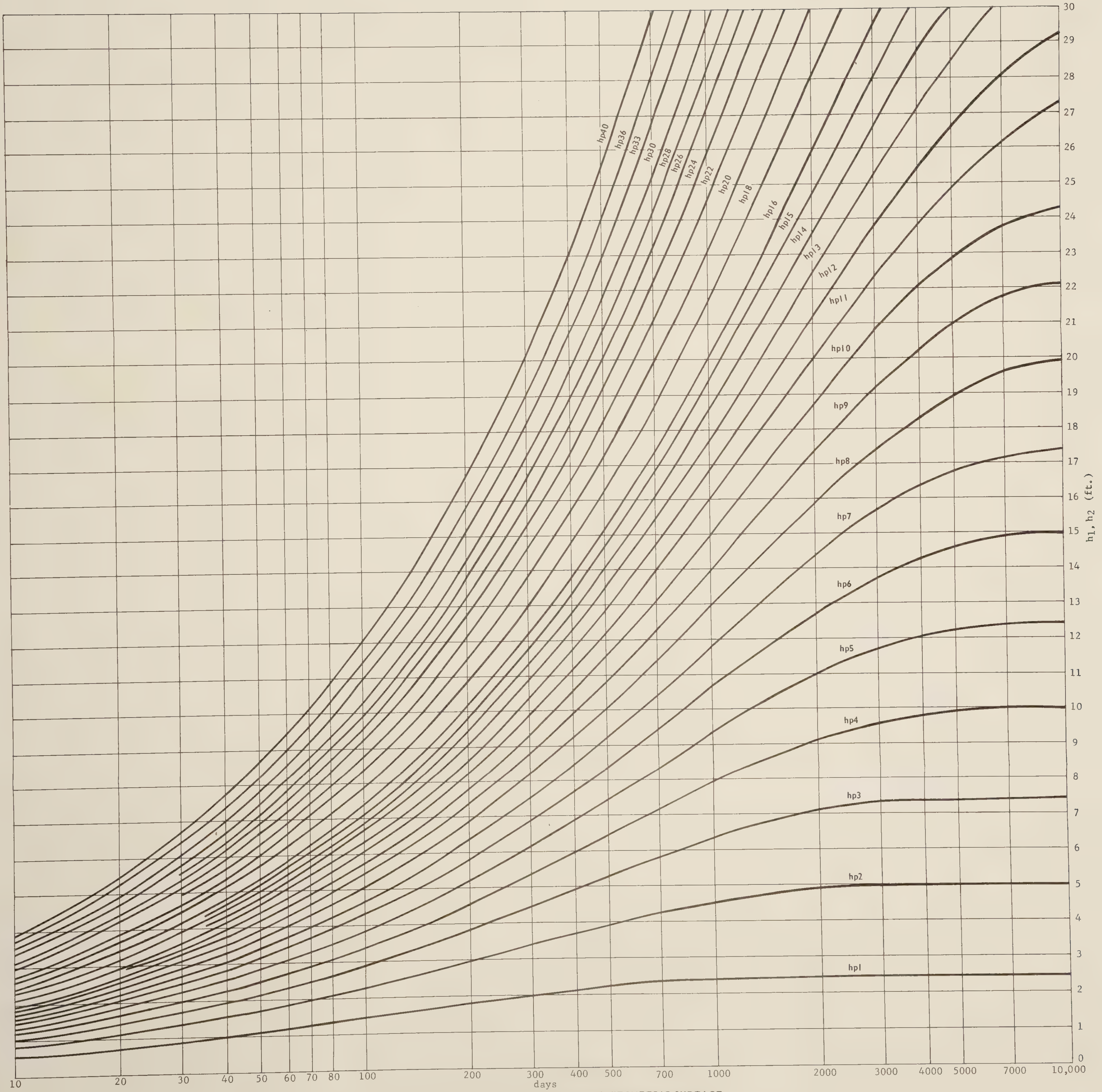

Figure 17. RELATION OF WATER TABLE TO PIEZOMETRIC SURFACE
Rising K= .001 A = +.0006 $h_1 < h_2$ (Equation Page 37)

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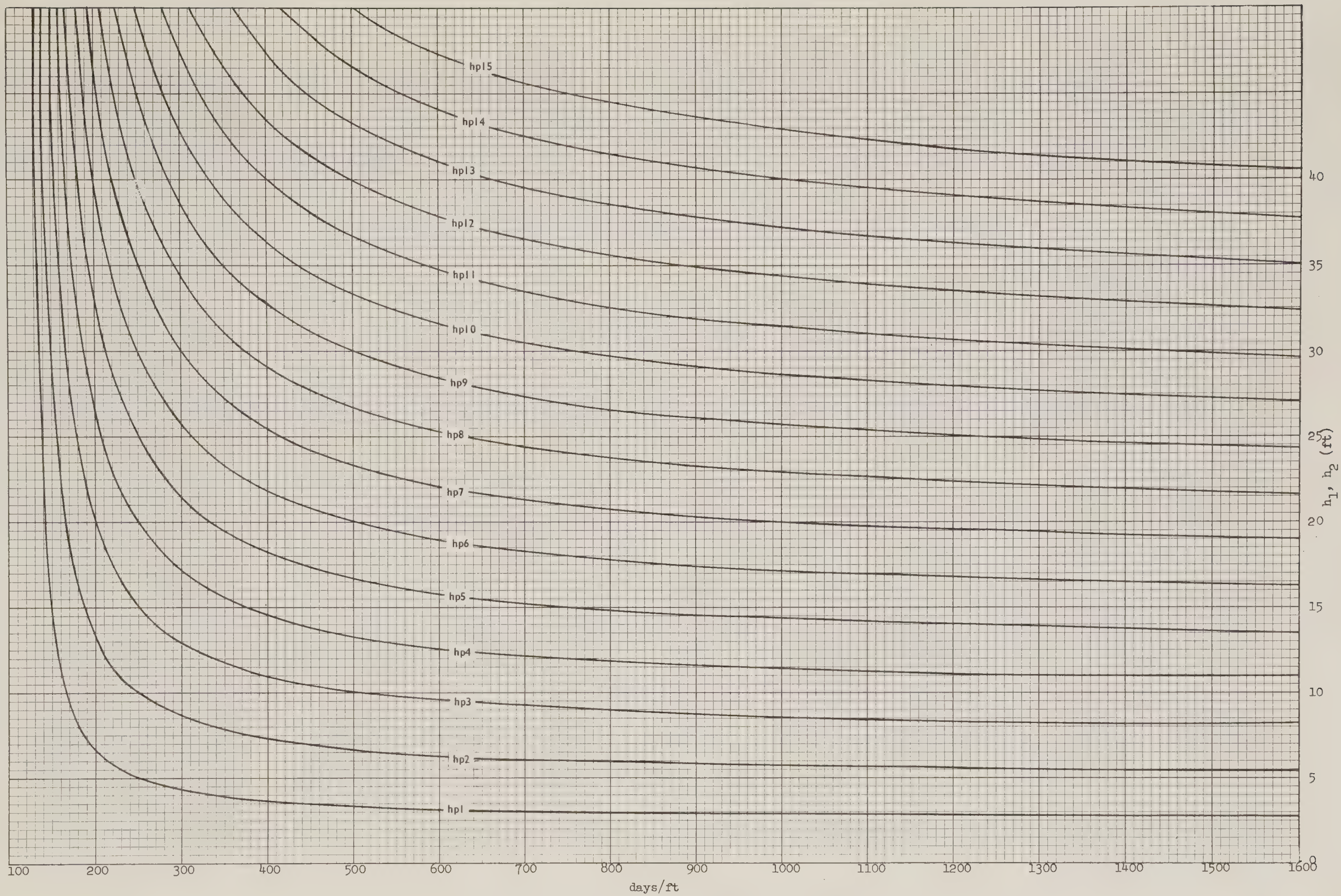

Figure 18. RELATION OF WATER TABLE TO PIEZOMETRIC SURFACE

Falling K = .001 A = +.006 $h_2 < h_1$

(Equation Page 37)

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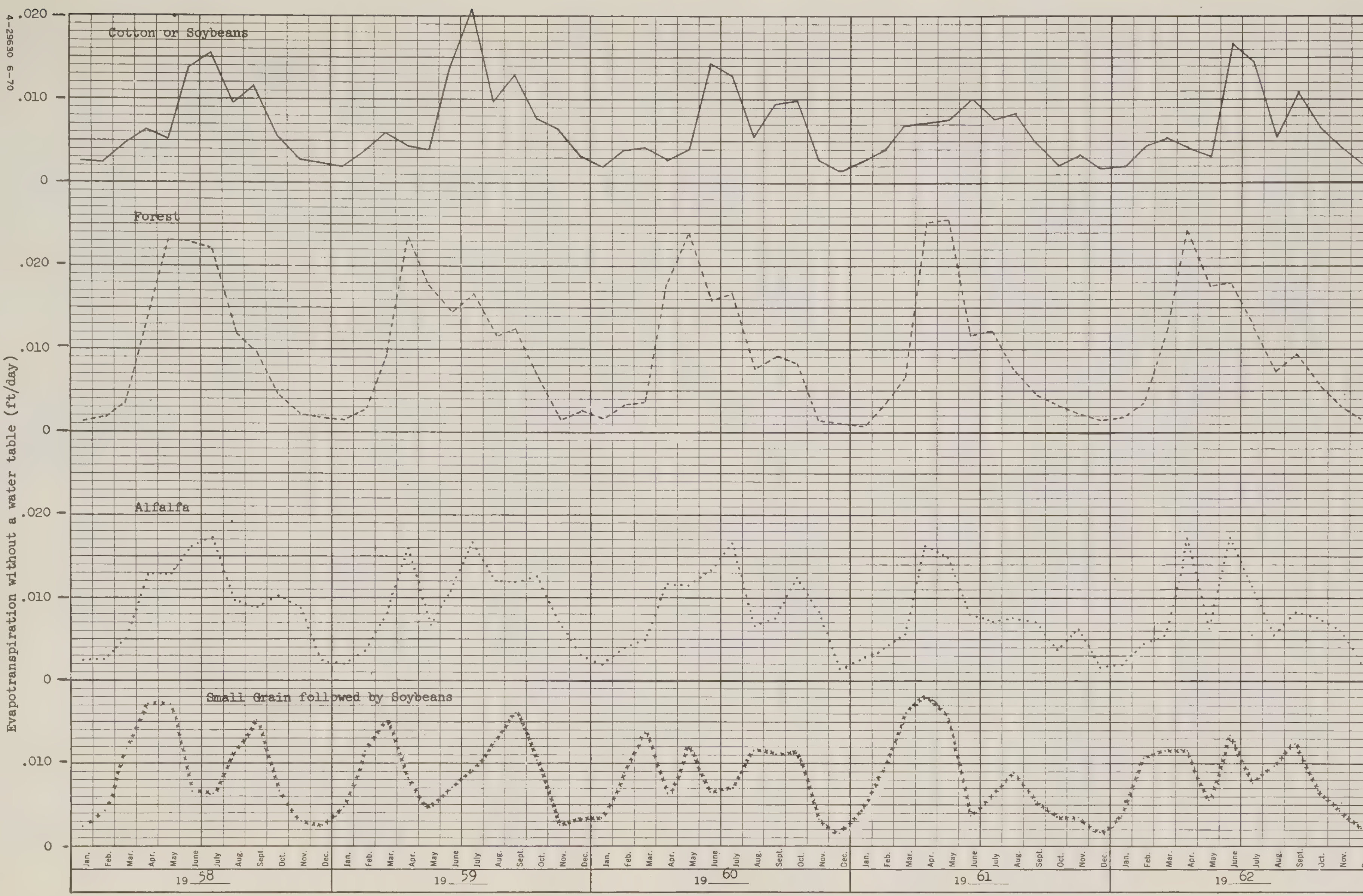

Figure 19. TOTAL EVAPOTRANSPIRATION FOR CROPS UNDER CONDITIONS OF NO WATER TABLE IN THE ROOT ZONE

as calculated are not accurate for the first part of 1958, as can be seen by comparing the water table hydrographs (examples are shown in the "Effects" part of this report) for 1958 with the following years.

b. Crop Response Estimates

The original plan of evaluating the effect of fluctuating water tables on crop production on the ARMPP was to get the necessary information and data from a review of the literature. A fairly thorough and exhaustive review was made with practically no information obtained that could be applied to the ARM PP study. There were some data on plant response to steady water tables. Some data existed for fluctuating water tables in the Netherlands but the crops were not applicable to the ARMPP. Many of the articles were abstracted and these and the reprints are on file.

It was found that generally, shallow rooted crops such as vegetables were benefited most by steady water tables between 12 and 18 inches deep. Deeper rooted crops, including alfalfa, had an optimum steady water table at about 24 inches. In general, indications were that crop response was not a result of water table per se; but rather to the aeration in the root zone and the demand of the roots for oxygen and of the plants for water.

Correspondence with the leading national and international authorities resulted in the consensus that valid estimates of the response of crops to water tables could best be made by those intimately associated with the conditions in the Arkansas River Valley.

The Agricultural Research Service assigned Dr. J. T. Wooley to assist the ARMPP staff by becoming familiar with the conditions adjacent to the Arkansas River and to provide methods of evaluating crop response to water tables. After he had made several trips observing the ARMPP area and had reviewed all the pertinent data he provided the following information and guidelines.

> "Adverse effects attributable to fluctuations of water tables are large only when the changes in height are fast enough to drown some roots without allowing time for replacement roots

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to develop in the non-saturated soil. And the changes have to last long enough to complete the drowning process. Then, for the damage to be most extensive, the water level has to drop rather fast, leaving behind dry soil from which newly developed roots can't get enough water. Rapid changes of this sort don't occur in the soils you are dealing with, so we can forget any harm that might be done by fluctuations themselves. Under normal conditions a root is continuously growing and senescing, and the plant can meet any fairly slow water table change with ease.

"To evaluate possible drowning of seeds during germination and before emergence, I suggest you use the following approximations. These are calculated for the field as a whole, rather than for individual seeds or plants. Temperature are at planting depth--4 inch would be OK except for alfalfa.

Crop	Days from planting to emergence	
	30°C (86°F)	20°C (68°F)
Corn	3 days	6 days
Cotton	4 days	10 days
Soybeans	4 days	8 days
Alfalfa	3 days	5 days

"At planting time the seeds use the oxygen from 0.025 cm of air depth per day at 30°C. If the soil has 20% air space, this is the oxygen from 0.125 cm of soil. This much oxygen could be dissolved in 0.8 cm of rainfall water. The seeds use half this much oxygen at 20°C.

"By emergence, the seeds and seedlings use the oxygen from 0.125 cm of air each day at 30°C. 4.0 cm of air-saturated water would be needed to carry this much oxygen. Again, the plants would use half as much at 20°C.

"Assume that corn, cotton, and alfalfa seed or seedlings before emergence can stand 6 hours of oxygen deficiency without damage, but that more than 6 hours of deficiency will kill them. This sharp death point is unreal, of course, but it will probably give just as good a result as the more complicated assumption that 3 hours is harmless and 9 hours is deadly, with a linear relationship between 3 and 9. You can try the latter assumption if you think it would be better.

"Assume that the soybean seedlings can stand one hour of oxygen deficiency, but more than that will kill them.

"At a permeability of 0.001 foot per day I don't think the saturated zone would ever extend down as far as the seed depth

for corn, cotton, and soybeans, except in depressions in the field. And the water would stand in those depressions under pre-project and post-project conditions except where the water table comes within a few inches of the surface. The condition we need to evaluate is the sealing off of the surface by water so that the seedling has to live on the air in the unsaturated zone between the saturated surface and the water table.

"Let's assume that the surface is sealed off for 24 hours after a rain, so that if we have rain on alternate days the surface remains impermeable to oxygen for the entire time. We can go through your daily water table calculation figures around planting time and find out whether there is any time at which we wouldn't have enough oxygen for the seedling. I suppose that when you go through this, it will turn out that post-project is just the same as pre-project. That is, I don't think the project will make any difference. For alfalfa, which is planted essentially on the surface, I don't think we need to make any calculations to know that the water table won't make any difference unless it comes right up to the surface.

"Now for damage during the main part of the growing season. Let's say that the oxygen use by the roots increases linearly with time from emergence to the time the plant gets about to its maximum vegetative size. For all the crops we will say the final or maximum use is 0.25 cm of air per hour at 30°C.

"If the soil has 20% air space, the roots then use the air from 1.25 cm of soil each hour, or from 30 cm (1 foot) of soil each day. The oxygen for one hour could be dissolved in 8 cm of air-saturated water. (This means that in an experiment such as was run at Illinois, where the water was going through the soil at maybe 2 cm per hour, a reasonable part of the oxygen needs of the plants could have been supplied by the water.) Corn, soybeans, and cotton will be undamaged if all roots are submerged (or lack oxygen) for 8 hours or less. They will be undamaged if half of the roots are submerged for 32 hours. They will die if the entire root system is submerged for 72 hours. For alfalfa we will make the same assumptions, except that the times will be 12 hours, 48 hours, and 108 hours, respectively. I would prefer to put these things into an equation, at least for the case where the roots are partly or completely submerged: For corn, cotton, soybeans:

$$\text{Loss of yield} = \frac{((\text{fraction of roots submerged})^2 \times \text{hours}) - 8}{64}$$

This equation squares the amount of roots submerged, and I think corresponds more closely to reality than a linear function does. Thus, if the roots are 60% submerged for 72 hours,

$$\text{Loss} = \frac{(0.36 \times 24) - 8}{64} = 8.64 - 8 = 0.01$$ which isn't much but if the roots are 60% submerged for 72 hours,

$$\text{Loss} = \frac{(0.36 \times 72) - 8}{64} = \frac{25.9 - 8}{64} = 0.28 \text{ a } 28\% \text{ loss in yield.}$$

With this equation I wouldn't use any times greater than 72 hours, because by the end of that time the unsubmerged part of the roots has had time to begin growing more roots if that is necessary. For alfalfa I would just increase the numbers

$$\text{Loss} \quad \frac{((\text{fraction of roots submerged})^2 \times \text{hours}) - 12}{96}$$

"Where we have the problem of roots running out of oxygen without actually being submerged, we don't have the complication of having some roots with oxygen and some without, so we probably don't need an equation. We can just try to calculate the length of time that the soil will be sealed off after the roots run out of oxygen.

"I forgot to mention that I intentionally built a possibility for growth stimulation into the equation I used above. That is, if 10% of the roots are submerged for 24 hours we have a loss of about (-.12), which would be a gain of about 12%. I don't know how reasonable this is. In fact, I don't know what we can do to evaluate beneficial effects in general. The only approach I can think of is a statistical one involving the "Agricultural Drought" possibilities, and saying that any damage due to drought is sure to be overcome if the water table is within one foot of the surface at the beginning of the season or within 4 feet of the surface at the end of the season. Under these assumptions we might be able to approximate the beneficial effects of a rise in water table.

Using the above information, workable values were obtained for estimating the effect of the depth of the water table and the length of time the soil surface was sealed upon the sufficiency of oxygen in the soil for plants.

To evaluate the sufficiency of oxygen in the soil for seed germination, and growth of plants, it is necessary to develop curves relating the amount of air space in the soil above the water table. The two curves in Figure 20 show approximations of air-volume distribution above a water table. The air content near the surface varies considerably depending upon the length of time since the preceding rainfall. The air-volume curve at time of emergence of the plants assumes no transpiration but the air-volume curve at full growth takes this into account and also considers the deficiency of moisture from rainfall during this period.

Figure 21 was developed from Figure 20 considering the oxygen use rates at the two growth periods. It gives the time required to deplete the oxygen in the soil at plant emergence at 20°C and also with full plant growth at 20°C, at 25°C, and at 30°C.

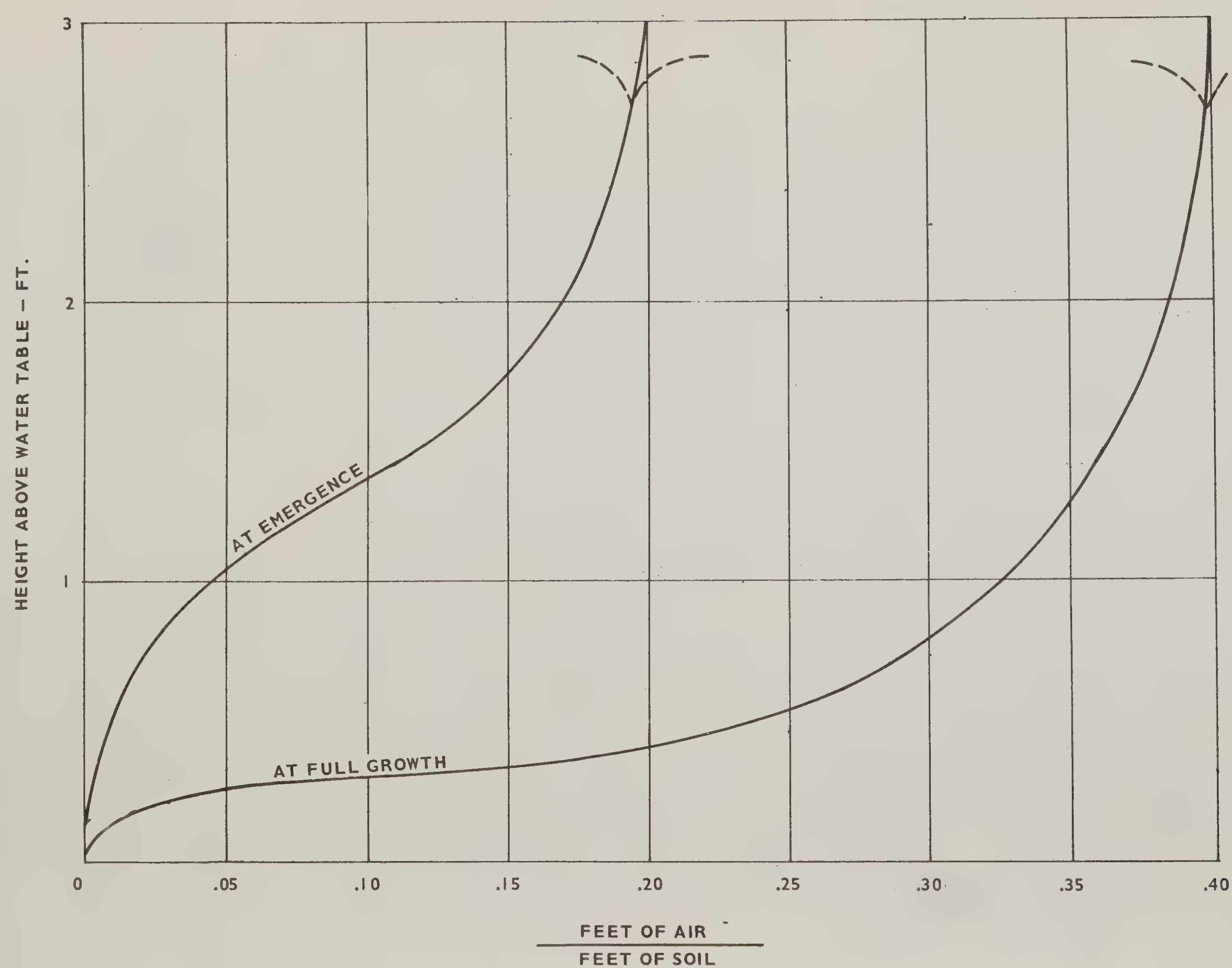

Figure 20. RELATIONSHIP OF AIRSPACE IN THE SOIL TO HEIGHT ABOVE WATER TABLE

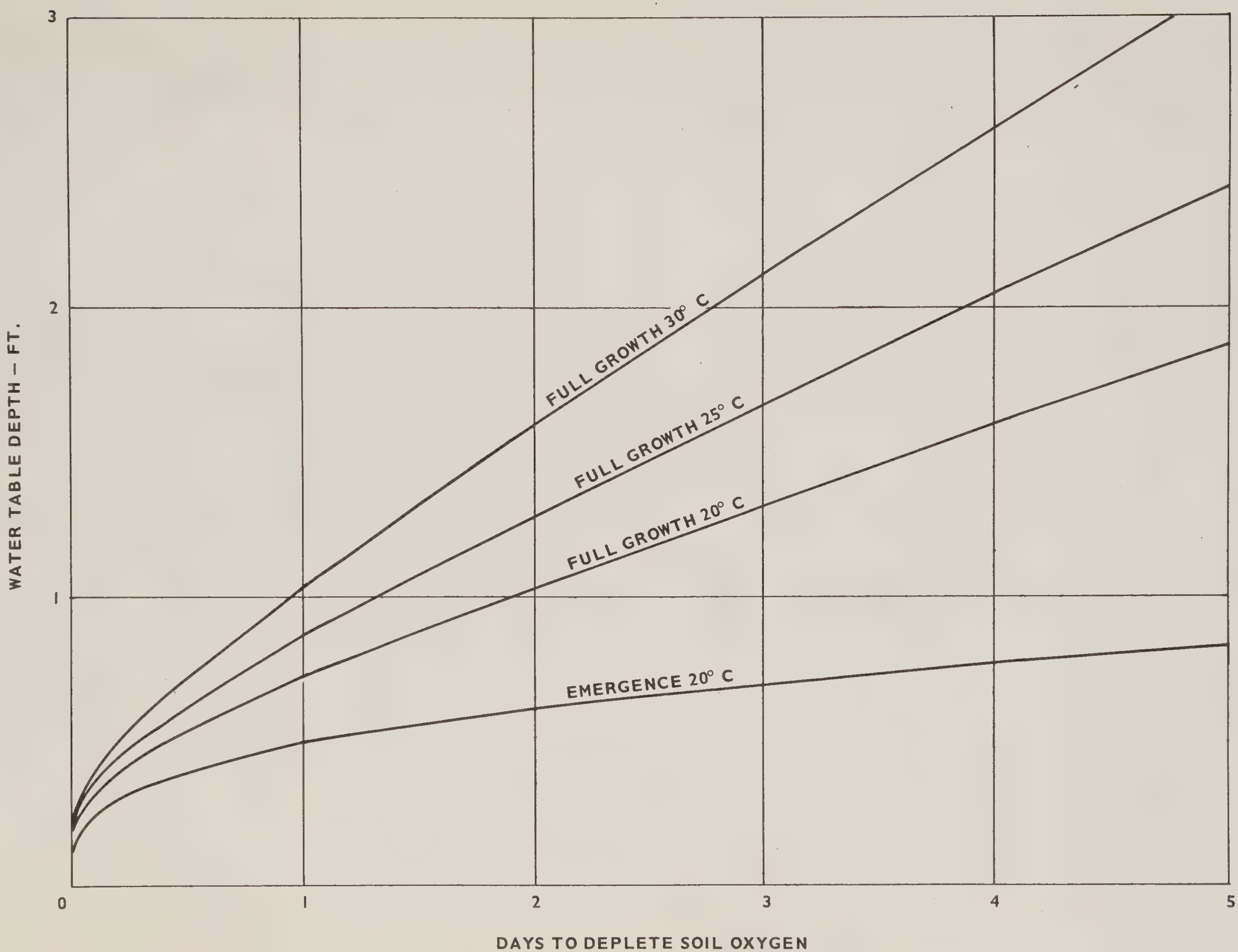

Figure 21. OXYGEN DEPLETION RATE TO DEPTH OF WATER TABLE

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The oxygen in the soil with a water table $\frac{1}{2}$ foot deep is sufficient to prevent drowning of seeds during germination at 20°C. Therefore, if the water table is deep enough for normal planting operations the seeds will not lack oxygen during germination.

At emergence the seedlings need the oxygen contained in .002 feet of air depth per day. There will be no damage with a 0.5-foot water table with the surface sealed 1 day; or a 1-foot water table for 8 days at 20°C; and half these times at 30°C. About nine hours without oxygen after the above times will be lethal.

At full growth, the plants need the oxygen contained in 0.2 feet of air depth each day at 30°C and $\frac{1}{2}$ this much at 20°C. Thus, at 30°C a soil with a water table at $\frac{1}{2}$ foot depth would contain sufficient oxygen for 5 hours, at a 1-foot depth for 1 day, at a 2-foot depth for 3 days, etc. At 20°C the length of time is twice as long. Cotton and soybeans will be undamaged the first 8 hours after the oxygen is depleted but will die after 4 days without oxygen.

The maximum length of time that the soil surface was saturated or sealed from the interchange of oxygen between the atmosphere and the root zone was determined using daily precipitation data, potential evaporation data, and evaporation of water from a soil following rainfall. A summary of the data on consecutive days of soil surface seal is shown on Table 19.

Table 19
Maximum Number of Consecutive Days of Soil Surface Seal by Rainfall
(Little Rock Precipitation)

	1958	1959	1960	1961	1962
January	2	3	3	2	2
February	2	3	3	2	3
March	4	2	2	6	2
April	5	1	0	2	1
May	2	1	2	1	1
June	1	3	4	2	2
July	2	3	1	2	1
August	1	2	1	2	1
September	2	2	2	1	2
October	0	2	2	1	3
November	2	1	1	2	2
December	2	3	4	3	2

The data in the preceding table were used with the relationships previously outlined for evaluating the sufficiency of soil oxygen for crops. The soil above water tables of 2 feet or deeper, considering observed occurrences of soil surface seal, had sufficient oxygen for normal plant growth from planting in May to maturity. One day without oxygen was considered to reduce yields to 75 percent, two days to 50 percent, 3 days to 25 percent, and 4 days to no yield. Predicted crop damage because of oxygen deficiency occurred at only a few locations.

The water table conditions and their effect on the production of cotton, soybeans, alfalfa, and forest are given in the following crop response guide.

Table 20

Crop Response Guide

Yield		Conditions for cotton, soybeans, and small grain
150%		Where the water table was from 1 to 3 feet deep at planting or not more than 4 feet deep during the growing season.
125%		Where the water table was from 4 to 5 feet deep during the growing season.
100%	A.	Where the water table was more than 5 feet deep during the growing season.
	B.	Less than 1 day of oxygen deficiency at full growth.
75%	A.	Where cotton planting was delayed 3 weeks.
	B.	Where soybean planting was delayed 4 weeks.
	C.	Where soybeans following small grain was delayed 2 weeks.
	D.	Oxygen deficiency for 1 day at full growth.
50%	A.	Where cotton planting was delayed 4 weeks.
	B.	Where soybean planting was delayed 6 weeks.
	C.	Where soybeans following small grain was delayed three weeks.
	D.	Oxygen deficiency for 2 days at full growth.
25%	A.	Where cotton planting was delayed 5 weeks.
	B.	Where soybean planting was delayed 8 weeks.
	C.	Where soybeans following small grain was delayed 4 weeks.
	D.	Oxygen deficiency for 3 days at full growth.
0%	A.	Where plantings were delayed more than for 25% yield.
	B.	Oxygen deficiency for 4 or more days at full growth.

Yield		Conditions for Alfalfa
150%		Where the water table was from 2 to 6 feet deep during the growing season.
125%		Where the water table was between 6 and 7 feet or where water table was from 2 to 6 feet half of the season and deeper than 7 feet the rest of the growing season.
100%	A.	Where the water table was deeper than 7 feet throughout the growing season.
	B.	Oxygen deficiency for 1 day or less at full growth.
75%	A.	Where the water table was 1 to 2 feet deep for 1 month during the growing season or less than 1 foot deep late in the growing season.
	B.	Oxygen deficiency for 2 days at full growth.
50%	A.	Where the water table was 1 to 2 feet deep for 2 months or less than 1 foot for 1 month at mid-season.
	B.	Oxygen deficiency for 3 days at full growth.
25%	A.	Where the water table was $\frac{1}{2}$ to 1 foot for 1 month early in the growing season, 2 months at mid-season, or 3 months in the late growing season.
	B.	Oxygen deficiency for 4 days at full growth.
0%		More severe conditions than 25%.

Yield	Conditions for forest
150%	Where the water table was from 2 to 8 feet deep during the growing season.
125%	Where the water table was from 8 to 10 feet deep during the growing season.
100%	Where the water table was deeper than 10 feet.
75%	Where the water table was 1 foot deep for 2 months of the growing season.
50%	Where the water table was 1 foot deep for 3 months or to the surface for 1 month during the growing season.
25%	If the water table was 1 foot deep for 4 months or to the surface for 2 months during the growing season.
0%	Where conditions were more severe than 25%.

Results are shown in section on "Effect of Multiple-Purpose Project on Agriculture and Forestry, Water Tables" with accompanying tables and maps that show the areas of effect, and the estimated magnitude of effect

for the various crops as indicated.

5. Economic Impacts

The major objective of this analysis was to determine if the farming economy was significantly affected by the installation of the navigation project. The major physical effects of the project were: 1) to remove land from private control through purchase of land in fee simple or through purchases of flooding easements, 2) to change water tables on agricultural lands, and 3) to modify drainage outlets for tributaries of the Arkansas River. Each of these factors has a potential effect on agricultural production and farm income. If large, the effect could be felt by agriculturally-related business, on tax revenues, and on the overall economy of the area.

Measuring the magnitude of the effect on the productive capacity of the resource base in relation to the agricultural resource base of the area as a whole was considered most important. If the effect on the productive land resources in the area were small, other adjustments to the effects of ARMPP would probably be minor.

Based on this reasoning, it was decided to estimate the productivity and use of not only the land resources directly affected by the project but also those land resources of the area that could be indirectly affected. The area used in the economic analysis followed county lines and thus was larger than the hydrologic or "study" area of 14,707 square miles. Figure 22 shows the economic sub-areas used in this analysis. Agricultural soils within the study area were classified on the basis of yield and production cost similarities. Cropland use for these soils was estimated. The crops considered were corn, grain sorghum, wheat, oats, alfalfa hay, other hay, rice, cotton, and soybeans. The latter two crops were considered under both dryland and irrigated conditions, and rice was considered only as an irrigated crop. All other land resources were accounted for as shown in Table 21.

Table 21
Land resources by sub-area

Sub-area	Cropland	Pasture & range	Forest total	Other land	Total inventory
			- - Acres - -		
Arkansas Mainstem	474,726	780,127	1,276,540	66,752	2,598,145
Bayou Meto	576,704	56,155	247,579	24,235	904,673
Cadron Creek	92,030	182,150	159,763	4,021	437,964
FPP 1/	64,626	333,310	440,793	14,293	853,022
Oklahoma	676,071	2,669,858	2,502,374	74,494	5,922,797
Total					10,716,601

1/ Those parts of Fourche La Fave, Petit Jean, and Poteau River in Arkansas that were included in the study.

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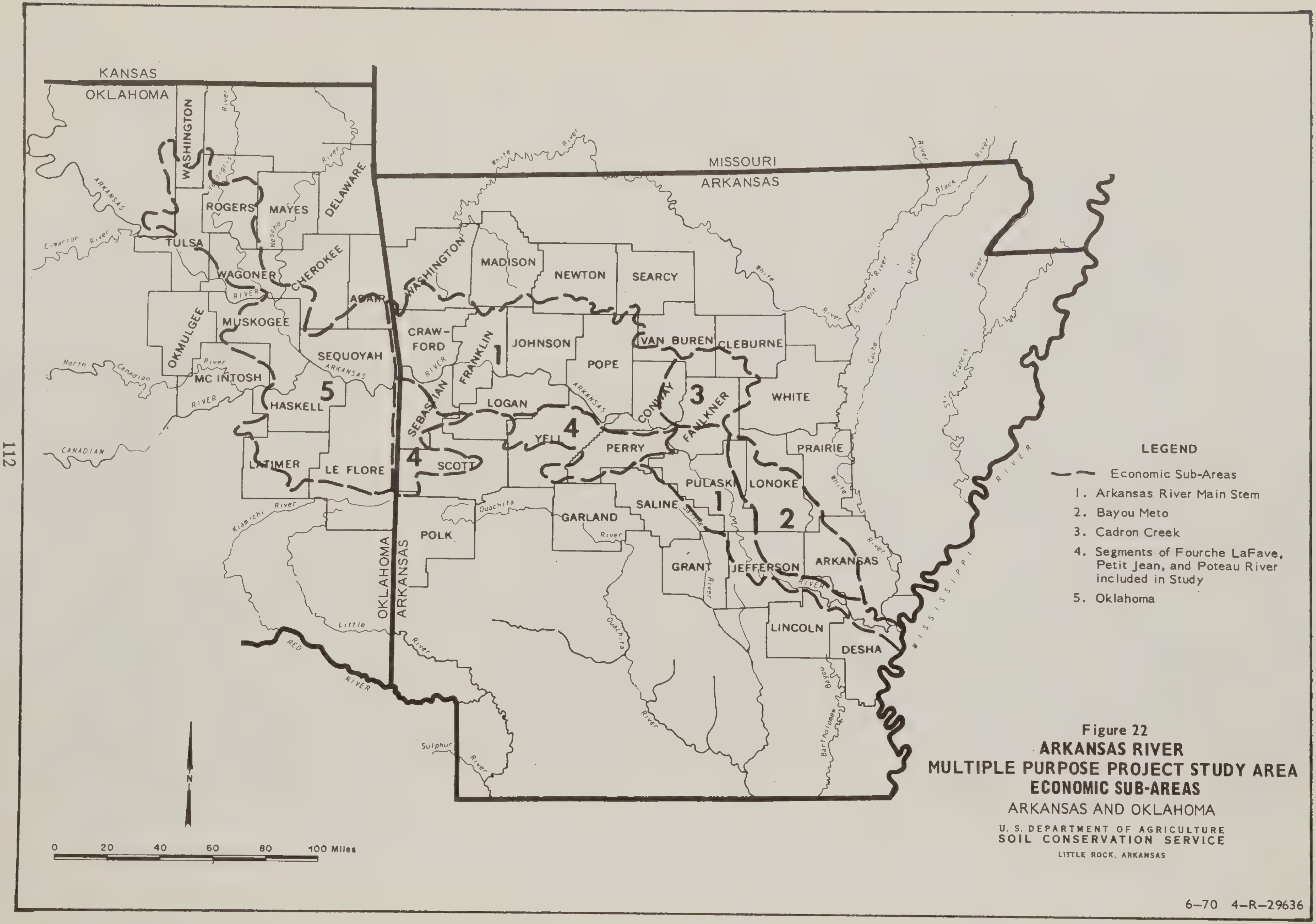

Figure 22
ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
ECONOMIC SUB-AREAS
ARKANSAS AND OKLAHOMA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

Since economic conditions within agriculture are rapidly changing and adjustments to the conditions brought about by ARMPP are related to these economic conditions, it was decided to estimate current and future resource productivities with and without the ARMPP project in place. The year 2000 was used to represent future conditions.

To locate the areas within the basin most affected by ARMPP, the basin was subdivided into five sub-areas - the Arkansas Mainstem; the Bayou Meto Basin; Cadron Creek; those parts of Fourche LeFave, Petit Jean, and Poteau Basin in the Arkansas portion of the study area; and the portion of the study area in Oklahoma. This approach to sub-area delineation was taken because it was compatible with past study boundaries and the delineation expected to be most useful in the future.

Data and Sources

Land Resources

The 1967 Conservation Needs Inventories of Arkansas and Oklahoma served as the basic source of land resource data for this study. Table 22 gives the relative importance of each land resources area (LRA) by sub-area for the study area. The ten land resource areas were combined into five groups. Land Resource Areas 112 (Cherokee Prairies), 117 (Boston Mountains), 118 (Arkansas Valley), and 119 (Ouachita Mountains) in Arkansas were taken as a group. Land Resource Areas 131 (Southern Mississippi Valley Alluvium), 132 (Southern Mississippi Valley Silty Uplands), and 133 (Southern Coastal Plain), were each considered separately and the seven land resource areas in Oklahoma were combined into a single group.

Soils within each of these land resource groups were classified into soil resource groups (SRG's) by combining soils with similar resource problems and production capabilities for cultivated crops. Land capability units (LCU's) which are composed of class, sub-class, and soil series, were the smallest soil units considered. Considered in this LCU classification are specific soil characteristics such as depth, texture, slope, erosion, and water holding capacity. In cases where only a few acres of soil with unique characteristics occurred, they were placed in a group where they fit best rather than under a separate grouping for each soil. As a result, 32 soil groups were formed for the study area. In the analysis, only cropland was considered; hence, only 22 SRG's came into the analysis. Table 23 shows the acres of each SRG for each of the sub-areas. A description of the soil groups is given in Appendix 1.

Each sub-area contains a variety of SRG's. The FPP sub-area has a relatively small amount of the better bottomland soils, SRG's 2 and 9, but a larger amount of the better upland soils, SRG 1. Bayou Meto has a large amount of the highly productive bottomland SRG's, 23 and 24. Cadron Creek sub-area has only small amount of the better bottomland SRG's. The Arkansas Mainstem sub-area has considerable amounts of the better bottomland SRG's, 2, 9, 23, and 24, as well as SRG 1, the good upland soils. In all of the Arkansas sub-areas, SRG's 6, 7, and 8 are soils not well adapted to crop production.

In the Oklahoma sub-area, SRG 1 consists of the Class I and II soils. SRG's 4, 5, and 6 are unsuited for crop production.

Table 22--Land resource areas as a percent of area by subbasin, ARMPP Study Area

Subbasin	Land resource area 1/									
	076	084	112	116	117	118	119	131	132	133
Arkansas Mainstem	--	--	2.54	--	5.73	70.16	4.99	10.09	0.97	5.52
Bayou Meto	--	--	--	--	--	12.27	--	52.25	33.97	1.51
Cadron Creek	--	--	--	--	0.97	99.03	--	--	--	--
FPP	--	--	--	3.56	--	73.44	23.00	--	--	--
Oklahoma	2.76	1.48	36.37	8.31	13.08	5.60	32.40	--	--	--
Total	1.50	0.81	20.79	4.54	8.54	31.58	20.97	6.76	3.06	1.45

1/ Numbers correspond to SCS designations - See previous page.

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Table 23--Soil Resource Groups by Subbasin - ARMPP

SRG	FPP	Bayou Meto	Cadron Creek	Arkansas Mainstem	Arkansas Total	Oklahoma
Arkansas			--- Acres ---			
1	236,622	28,839	223,016	578,129	1,066,606	1,494,899
2	102,381	4,948	11,910	173,533	292,772	1,320,257
3	66,565	14,624	38,741	214,139	334,069	115,056
4	91,584	13,038	20,688	123,694	249,004	208,658
5	100,983	13,263	39,225	133,950	287,421	574,517
6	17,701	--	1,956	140,683	160,340	2,209,410
7	14,511	--	--	101,847	116,358	
8	212,222	34,115	89,559	632,500	968,396	
9	10,453	--	12,869	74,623	97,945	
17	--	15,501	--	--	15,501	
18	--	36,211	--	8,380	44,591	
21	--	192,170	--	7,333	199,503	
22	--	60,103	--	9,429	69,532	
23	--	92,064	--	78,704	170,768	
24	--	264,678	--	134,790	399,468	
25	--	114,371	--	32,397	146,768	
26	--	--	--	11,908	11,908	
27	--	3,157	--	3,032	6,189	
28	--	3,946	--	--	3,946	
29	--	6,065	--	60,955	67,020	
30	--	--	--	14,295	14,295	
31	--	--	--	6,113	6,113	
32	--	1,516	--	19,505	21,021	
33	--	6,064	--	29,659	35,723	
34	--	--	--	7,789	7,789	
36	--	--	--	758	758	
Total	853,022	904,673	437,964	2,598,145	4,793,804	5,922,797

Basin Total 10,716,601

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Data on Corps of Engineers land purchases for ARMPP were obtained from the Corps of Engineers. With assistance of district and soil scientist, using segment maps as a basis, the areas purchased were assigned to the appropriate SRG. Table 24 indicates the area purchased and the percent that was cropland. All of this was in the Arkansas Mainstem and the Oklahoma sub-areas.

In the area purchased in the Arkansas sub-area, about 75 percent of the land was in the SRG's, 2, 9, 23, and 24, the better bottomland SRG's. In the Oklahoma sub-area over 90 percent of the land purchased was in SRG 1, the better soils in that area.

For the future, adjustments were made in the land resource base to reflect changes resulting from land being used for other purposes. The amount of land going out of inventory was assumed to be related to the increase in population. For 1967, it was estimated that 0.44 acres of urban and built-up land was required for each person. Population was projected to increase by about 848,000 by the year 2000; therefore, it was assumed urban and built-up land would increase by 263,244 acres by 2000. As a result, inventory acreage was assumed to decrease by that amount or 0.023 percent. The percentage decrease was applied equally to all SRG's.

In addition, the cropland base was increased for land clearing that is expected to occur in the study area. It is estimated that in the Bayou Meto 10.6 percent of the existing forest will be cleared by 2000. The clearing is estimated to be proportional among soil groups. The area south and east of Little Rock and north of the Arkansas River is projected to have the same clearing pattern as the Bayou Meto. The area below Little Rock south and west of the Arkansas River and all the area west of Little Rock are projected to have no net clearing of land for crop production.

Areas affected by the changed water table were delineated in the projectional study. The affected areas were allocated to the appropriate SRG, on the basis of judgement of local soil scientists. It was assumed that the affected acreage had the same percent cropland as the SRG. The following shows the amount of cropland in SRG's in Arkansas and Oklahoma that was assumed could be affected.

SRG	Acres
ARKANSAS	
2	62
9	2,690
23	10,018
24	55,144
OKLAHOMA	
3	2,435

The area to be benefited from feasible upstream watershed projects was estimated from the watershed investigation reports. The benefited area was assumed to have the same percent cropland as the floodplain. In most cases the total flood plain had been indicated as the benefited area.

Table 24
Corps of Engineers
Land purchases, percent cropland and acres cropland by sub-area by SRG.

Sub-area	Soil Group	Acres Purchased	Percent Cropland	Acres Cropland
Arkansas Mainstem	1	2,840	16	454
	2	35,107	47	16,500
	3	1,688	12	202
	4	2,106	18	379
	5	2,994	16	479
	6	756	1	8
	7	160	0	0
	8	2,232	2	45
	9	7,756	69	5,352
	18	624	88	549
	21	799	100	799
	22	1,249	0	0
	23	5,955	77	4,586
	24	405	50	203
	26	1,081	0	0
Subtotal		65,752		29,556
Oklahoma	1	78,204	32	25,025
	4	4,606	0	0
Subtotal		82,810		25,025
GRAND TOTAL		148,562		54,581

The benefited area by sub-areas by SRG is shown in Table 25.

Crop Yields per Acre

Present yields were developed for each crop for those SRG's in which the crop was grown. The procedure was to first develop a yield for each of the groups of LRA's by selecting a sample of counties within the LRG and mathematically fitting a trend line to the Statistical Reporting Service's annual crop yield data for the years 1959-68. The yields were then projected to the year 2000 using data developed nationally by ERS for a project on National Inter-regional Analysis and Projection. These yields were then used as a first estimate.

The SRG's were then arrayed according to their productivity by crop. Using previous studies, SCS technical guides, the yields developed for total LRG's, and yields for dominant soils, present crop yields were estimated for each SRG. For projections of yields to 2000, each SRG's productive capacity was evaluated and a percentage change in yield was determined. Agricultural agronomists reviewed the results which are given as Flood Zone 5 in Appendix 1. The present yield and indices for 2000 are shown in Appendix 1.

Using the flood free yield as a basis, yields were developed for each SRG in which reduced yields from water hazard were expected. In the Bayou Meto, these were the yields developed for the current Type IV Study. In the same SRG's in adjacent these yields were used.

Flood Zone 1 is soil flooded each year. Flood Zone 3 is soil flooded less than once a year. This latter occurs only in the Bayou Meto. Flood Zones 2 and 4 are 1 and 3 after development. The yields in 2 and 4 are based on the assumption of 80 percent protection and 75 percent participation in the program, giving a 60 percent increase as a result of development.

Flood Zone 6 is that affected by the change in the water table associated with construction of the various locks and dams. A part of the results of the projectional study was an estimate of the changes in yields due to change in water table.

The flood zone 6 yield was established by increasing the flood zone 5 crop yield by the estimated average water table effect or reported in the "Effects" section of the projectional study. These are 35 percent for corn, sorghum, wheat, oats, and other hay. Alfalfa and cotton yields were increased by 26 percent and soybeans by 29 percent.

Current Land Use

Conservation Needs Inventory (CNI) served as the basic information source for the broad land use categories. Cropland, Forest, Pasture and Range, and Other, as well as Non-Inventory are the basic breakdown in CNI.

With respect to cropland, only broad categories are given, i. e., corn and sorghum, other row crops, close grown crops, etc. To establish estimates of land use at the crop level, the following procedure was used.

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Table 25 --Areas to be benefited for Upstream feasible projects by SRG by Sub-area, ARMPP

Sub-area	Arkansas soil resource groups												Oklahoma
	2	4	5	9	18	21	22	23	24	25	32	33	1
						- - - Acres - - -							
Mainstem	55,850	13,141	11,499	31,210		4,928		31,210	8,433	6,575	71	1,643	
Bayou Meto					2,901	151,426	21,274	4,171	170,832	70,925		1,009	
FPP	1,226	176	591	197									
Cadron	75	181	478	893									
Oklahoma													53,423
Total	57,151	13,498	12,568	32,300	2,901	162,354	21,274	35,381	179,265	77,500	71	2,652	53,423

Forms were prepared by SRG with CNI totals given; e. g., the CNI total acres for corn and sorghum. On the basis of Census and Statistical Reporting Service data, a tentative breakdown within this total, i.e., corn for grain, sorghum for grain, and other was made. Then after this was done for all categories of the major crops, Area Conservationists and Soil Scientists in the study area made independent estimates of crop areas in the sub-areas. These were compared and land use patterns for each SRG for each sub-area were made. These are shown in Appendix 1.

Throughout the analysis, the current land use pattern, percentagewise, was applied to the land resource base. By using this method, the impact of ARMPP could be assessed with at least part of the other conditions held constant.

Prices

To establish values of production, the current normalized price was taken from the Interim Price Standards for Planning and Evaluating Water and Land Resources done by an Interdepartmental Staff Committee of the Water Resource Council. These prices are given in Table 26.

Table 26
Prices assumed ARMPP Study

Product	Unit	Price
Corn	Bu.	$1.17
Soybeans	Bu.	2.47
Cotton	Lbs.	0.26
Oats	Bu.	0.68
Wheat	Bu.	1.27
Rice	Lbs.	0.0475
Other hay	Ton	23.54
Alfalfa	Ton	23.54
Sorghum	Bu.	1.11

Source: Interim Price Standard for Planning and Evaluating Water and Related Land Resources. Water Resources Council, April 1966.

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EFFECT OF MULTIPLE PURPOSE PROJECT ON AGRICULTURE AND FORESTRY

1. Water Table

The following tables and hydrographs illustrate how the crops responded to water tables following the procedure outlined in the methodology section. These are included as examples and represent a variety of conditions that are present in more than 4000 similar tables and hydrographs. Maps showing the estimated crop response effects in their entirety are presented later in the report. Of the 75,651 acres where the water table will have an effect on production, there will be little change on 24 percent of the area, the crops on 75 percent of the area will be measurably benefited, and the crops on 1 percent of the area will be damaged.

Table 27 shows data that are pertinent to the interpolation and development of the piezometric-surface hydrographs from which water tables were calculated by means of the functional relationship described in Methodology and are included as examples. Table 28 shows the results of crop effect estimates for the water table hydrographs also included as examples in this report.

Figures 23 through 47, Page 133 through Page 157, represent about 0.5 percent of the hydrographs of water table and piezometric surface and are included as examples. They show the types of conditions that existed at 13 locations in the study area. Both pre- and post-project conditions are included. Figures 48 through 55, Pages 158 through 165, are the Arkansas River stage hydrographs and post-project pool hydrographs that were used to correlate and interpolate the piezometric surface hydrographs for the calculation of water-table hydrographs shown as examples (Figures 23 through 47).

Figure 56, Page 166, shows the piezometer locations and the type and intensity of study that was made on the data from them. Figure 56 also shows the areas where crops or forest will be affected by the water table. Included also on Figure 56 are the locations of the river and pool hydrographs shown on Figures 48 through 55 and the approximate area of easement or purchase by the Corps of Engineers. Table 7, Page 39, supplements Figure 56 by giving the analysis made at each piezometer location.

Figures 57 through 60, Pages 176 through 190, show the approximate areas and estimated magnitude of the effects of the water tables on small grain followed by soybeans, cotton, soybeans, alfalfa, and forest. The effects of the water tables on forest were not studied for the reaches above Dardanelle lock and dam (reaches 10 through 18). The accuracy of the delineations are limited by the scarcity of piezometric data and the poor detail and accuracy of topographic information. Post-project stage data were not available for Reach No. 12, so it is not included in the study.

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Table 29 shows the acreages by reaches of the areas delineated in Figures 57 through 60. Table 30 is a summary of all the reaches and shows the potential crop yield changes from the ARMPP. Table 31 shows the total acres of crop affected and the magnitude of affect assuming land use of 10 percent small grain followed by soybeans, 7 percent cotton, 71 percent soybeans, 4 percent alfalfa, and 8 percent forest.

In Table 27, Page 123, Column 1 shows the location of the piezometers from which data were obtained for the study. These locations are shown on the maps in Figure 56, Pages 166 to 171. Columns 2 through 11 are data which were pertinent to the correlation and interpolation of periodic piezometric data into continuous hydrographs. Columns 12 and 13 are soils data that were considered in calculating the water tables from the piezometric surface hydrographs. The permeability values (K) shown in Column 12 are also shown on the sample hydrographs (Figs. 23 through 47) along the left hand margin. Also located along the left hand margin of each hydrograph is the elevation of the base of fine textured soil material overlying coarse textured material. This is indicated by "ho". If the K value is 1 or 0.1 no "ho" is shown and the water table and piezometric surface hydrographs are considered to be practically the same. Where pre-project piezometric data could not be correlated, as at piezometer T1N-R11W-3abb, because of undetermined dominating factors, no projection was attempted and it was assumed that there would be no change because of the ARMPP.

Table 28, Page 124, shows the crop response estimates that were made on the sample water table hydrographs. A response of 100 indicates that

(Text continued on Page 172)

Table 27
Data Pertinent to the Correlation and Interpolation of River and Pool Stages with Piezometric Surface Data and Soil Factors Used to Calculate the Water Tables From the Piezometric Surface Hydrographs

Piezometer Location	Ground Surface Elevation	Average Piezometric Surface Elevation Preproject	Average Piezometric Surface Elevation Post project	Peak Piezometric Surface Elevation Preproject	Peak Piezometric Surface Elevation Postproject	Peak River Stage Preproject	Peak River Stage Postproject	Project Mile of River Hydrograph Used to Correlate Piezometric Hydrograph	River Hydrograph Used for Piezometric Surface Correlation	Major Factor Causing Piezometric Surface Fluctuations	Surface Soil Permeability (K in ft./day)	Thickness of Fine Textured Material From Base to Avg. Post-project Piezometric Surface (feet)
	-Feet - MSL-											
REACH 2												
T8S-R3W-27 ccc	165	155	163	161	165	164	166	26.5	60 day average	River stage	.1	12
T8S-R4W-8 bbb	173	163	165	167	169			-	-----	Pumping	.001	12
REACH 3												
T6S-R6W-17 dca	186	177	182	181	183	190	192	61.3	60 day average	River stage	.001	19
T4S-R7W-31 ccb	193	180	186	183	189			-	-----	Pumping	.01	6
T6S-R8W-33 bab	196	189	195	192	198			-	-----	Pumping	.001	5
REACH 5												
T3S-R10W 23 bcc	224	204	214	212	215	213	215	92	60 day average	River stage	.001	53
REACH 6												
T1N-R11W 30 abb	245	239		241				Does not correlate		Fourche Bayou or Hill	.1	
T1S-R11W 4 add	237	231	232	236	235	229	231	116.1	60 day average	River stage	.001	8
REACH 7												
T2N-R13W 10 cad	253	235	250	250	252	255	252	133.5	10 day average	River stage	.001	25
T2N-R13W 16 bac	256	240	250	254	252	255	252	133.5	10 day average		1	
REACH 13 Oklahoma												
T10N-R27E 3 cab	404	396	397	409	402	408	404	302.7	10 day average	River stage	.001	7
REACH 17												
T16N-R18E 9 bbb	516	502	512	515	516	525	521	408.7	10 day average	River stage	.001	13
REACH 18												
T18N-R16E 1 aaa	540	529	534	539	537	542	541	425.7	30 day average	River stage	.001	24

Table 28

(Sheet 1 of 3)

Results of Estimated Crop Response to Water Table Hydrographs Included as Examples in This Report

Piezometer Location	Crop	Pre-project 1958	1959	1960	1961	1962	Post-project 1958	1959	1960	1961	1962	Avg. Pre-project	Avg. Post-project	Change
		Percent												
REACH 2														
T8S-R3W-27 ccc	Small grain	- - - -100 - - - - - - -					150	150	150	0	150	100	120	20
	-Soybeans	- - - -100 - - - - - - -					150	125	150	50	150	100	125	25
	Cotton	- - - -100 - - - - - - -					150	150	150	0	150	100	120	20
	Soybeans	- - - -100 - - - - - - -					150	150	150	50	150	100	130	30
	Alfalfa	125	100	100	125	100	25	150	150	0	150	110	105	-5
	Forest	150	100	125	150	125	50	150	150	25	150	130	110	-20
T8S-R4W-8 bbb	Alfalfa	- - - -100 - - - - - - -					100	125	125	125	125	100	120	20
	Forest	125	125	125	125	100	150	150	150	150	150	120	150	30
REACH 3														
T6S-R6W-17 dca	Sm. gr.-Soy.	- - - -100 - - - - - - -					150	150	150	150	150	100	150	50
	Cot. or Soy.	- - - -100 - - - - - - -					150	150	150	150	150	100	150	50
	Alfalfa	100	100	125	100	150	150	150	150	150	150	115	150	35
	Forest	150	150	150	150	150	150	150	150	150	150	150	150	0
T4S-R7W-31-ccb	Small grain	- - - -100 - - - - - - -					100	100	125	125	125	100	115	15
	Cot. or Soy.	- - - -100 - - - - - - -					100	100	125	150	150	100	125	25
	Alfalfa	- - - -100 - - - - - - -					150	125	150	150	150	100	145	45
	Forest	- - - -100 - - - - - - -					150	150	150	150	150	100	150	50
T6S-R8W-33 bab	Sm. gr.-Soy.	- - - -100 - - - - - - -					150	150	150	150	150	100	150	50
	Cotton	- - - -100 - - - - - - -					0	50	50	150	50	100	60	-40
	Soybeans	- - - -100 - - - - - - -					75	75	150	150	150	100	120	20
	Alfalfa	150	125	150	125	150	150	150	150	150	150	140	150	10
	Forest	150	150	150	150	150	150	150	150	150	150	150	150	0

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Table 28

(Sheet 2 of 3)

Results of Estimated Crop Response to Water Table Hydrographs Included as Examples in This Report

Piezometer Location	Crop	Pre-project 1958	Pre-project 1959	Pre-project 1960	Pre-project 1961	Pre-project 1962	Post-project 1958	Post-project 1959	Post-project 1960	Post-project 1961	Post-project 1962	Avg. Pre-project	Avg. Post-project	Change
		Percent												
REACH 5														
T3S-R10W-23 bcc	Forest	100					125	125	125	125	125	100	125	25
REACH 6														
T1N-R11W-30 abb														
T1S-R11W-4 add	Small grain	125	100	150	125	125	125	125	150	125	150	125	135	10
	Sm. gr.-Soy.	125	100	150	125	125	125	125	150	125	125	125	130	5
	Cot. or Soy.	150	125	150	150	125	150	125	150	150	150	140	145	5
	Alfalfa	150	150	150	150	150	150	150	150	150	150	150	150	0
	Forest	150	150	150	150	150	150	150	150	150	150	150	150	0
REACH 7														
T2N-R13W-10 cad	Sm. gr.-Soy.	100					150	150	150	150	150	100	150	50
	Cot. or Soy.	100					150	150	150	150	150	100	150	50
	Alfalfa	100					150	150	150	150	150	100	150	50
	Forest	100					150	150	150	150	150	100	150	50
T2N-R13W-16 bac	Alfalfa	100					125	125	125	125	125	100	125	25
	Forest	100					150	150	150	150	150	100	150	50

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Table 28
(Sheet 3 of 3)

Results of Estimated Crop Response to Water Table Hydrographs Included as Examples in This Report

Piezometer Location	Crop	Pre-project 1958	Pre-project 1959	Pre-project 1960	Pre-project 1961	Pre-project 1962	Post-project 1958	Post-project 1959	Post-project 1960	Post-project 1961	Post-project 1962	Avg. Pre-project	Avg. Post-project	Change
		Percent												
REACH 13														
Oklahoma														
T10N-R27E-3 cab	Small grain	100	100	100	100	125			100			105	100	- 5
	Sm. gr.-Soy.	100	100	125	125	100			100			110	100	-10
	Cotton	125	125	150	150	125			100			135	100	-35
	Soybeans	125	125	150	150	125			100			135	100	-35
	Alfalfa	150	150	150	150	150	150	125	150	150	150	150	145	- 5
REACH 17														
T16N-R18E 9 bbb	Sm. gr.-Soy.			100			150	150	150	150	150	100	150	50
	Cot. or Soy.			100			150	150	150	150	150	100	150	50
	Alfalfa			100			150	150	150	150	150	100	150	50
REACH 18														
T18N-R16E-1 aaa	Small grain			100			100	100	125	125	125	100	115	15
	Sm. gr.-Soy.			100			100	100	125	125	125	100	115	15
	Cot. or Soy.			100			125	150	150	150	150	100	145	45
	Alfalfa			100			150	150	150	150	150	100	150	50

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Table 29

(Sheet 1 of 4)
POTENTIAL CROP YIELD CHANGES FROM ARMPP (Acres)

Reach	Crop	-100	-75	-50	-25	0	25	50	Total
		Changes in Yields (Percentage Points)							
2	Small grain-soybeans						6,080	10,420	16,500
	Cotton		110		130	2,060	8,880	11,880	23,060
	Soybeans					2,190	8,990	11,880	23,060
	Alfalfa			160		14,650	45,950	5,330	66,090
	Forest			550	260	18,720	55,550	380	75,460
3	Small grain-soybeans					2,280	5,590	8,120	15,990
	Cotton	390		1,320	530	9,010	4,630	11,440	27,320
	Soybeans					9,410	5,850	12,060	27,320
	Alfalfa					2,530	21,580	19,500	43,610
	Forest				610	17,880	33,450	13,840	65,780
4	Small grain-soybeans								
	Cotton					330			330
	Soybeans					330			330
	Alfalfa						390	260	650
	Forest						860	260	1,120

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Table 29

(Sheet 2 of 4)

POTENTIAL CROP YIELD CHANGES FROM ARMPP (Acres)

Reach	Crop	Changes in Yields (Percentage Points)							Total
		-100	-75	-50	-25	0	25	50	
5	Small grain-soybeans					150	500	400	1,050
	Cotton					2,720	1,600	420	4,740
	Soybeans					2,720	1,600	420	4,740
	Alfalfa				150	6,370	2,680	2,200	11,400
	Forest					1,090	10,660	3,610	15,360
6	Small grain-soybeans					510	140		650
	Cotton					790		150	940
	Soybeans					790		150	940
	Alfalfa					920	370		1,290
	Forest				240	680		280	1,200
7	Small grain-soybeans					600	450	760	1,810
	Cotton					370	630	860	1,860
	Soybeans					370	630	860	1,860
	Alfalfa					910	510	890	2,310
	Forest					800	620	890	2,310

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Table 29

(Sheet 3 of 4)
POTENTIAL CROP YIELD CHANGES FROM ARMPP (Acres)

Reach	Crop	Changes in Yields (Percentage Points)							Total
		-100	-75	-50	-25	0	25	50	
8	Small grain soybeans				140				140
	Cotton				140				140
	Soybeans				140				140
	Alfalfa			140	290				430
	Forest			220	70	140			430
10	Small grain soybeans					100			100
	Cotton					150			150
	Soybeans					150			150
	Alfalfa					50	100		150
13	Small grain soybeans					420		190	610
	Cotton				150	270		190	610
	Soybeans				150	270	190		610
	Alfalfa					290	130	640	1,060

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Table 29

(Sheet 4 of 4)
POTENTIAL CROP YIELD CHANGES FROM ARMPP (Acres)

Reach	Crop	-100	-75	-50	-25	0	25	50	Total
		Changes in Yields (Percentage Points)							
17	Small grain-soybeans				80	1,150	410	2,630	4,270
	Cotton			80	180	310	2,480	2,240	5,290
	Soybeans			80	180	900	1,890	2,240	5,290
	Alfalfa			170	60	800	1,380	4,110	6,520
18	Small grain-soybeans						1,490	730	2,220
	Cotton					160	1,330	1,890	3,380
	Soybeans					160	1,330	1,890	3,380
	Alfalfa						420	3,140	3,560

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Table 30

POTENTIAL CROP YIELD CHANGES FROM ARMPP (Acres)

Crop	Changes in Yields (Percentage Points)							
	-100	-75	-50	-25	0	25	50	TOTAL
Small grain-soybeans				220	5,310	14,660	23,250	43,340
Cotton	390	110	1,400	1,130	16,170	19,550	29,070	67,820
Soybeans			80	470	17,290	20,480	29,500	67,820
Alfalfa			470	500	26,520	73,510	36,070	137,070
Forest (Reaches 2-9)			770	1,180	39,310	101,140	19,260	161,660

Table 31

Acres of Crop Yield Changes from ARMPP Assuming Land Use of 10% Small Grain-Soybeans, 7% Cotton, 71% Soybeans, 4% Alfalfa, and 8% Forest

Crop	Changes in Yields (Percentage Points)							Total	Average Weighted Percentage Yield Increase
	-100	-75	-50	-25	0	25	50		
Small grain-Soybeans				22	531	1,466	2,325	4,334	35.2%
Cotton	27	8	98	79	1,132	1,369	2,035	4,748	26.5%
Soybeans			57	334	12,276	14,541	20,945	48,153	29.1%
Alfalfa			19	20	1,061	2,940	1,443	5,483	26.3%
Forest			62	94	3,145	8,091	1,541	12,933	21.2%
Total	27	8	236	549	13,145	28,407	28,289	75,651	27.7%

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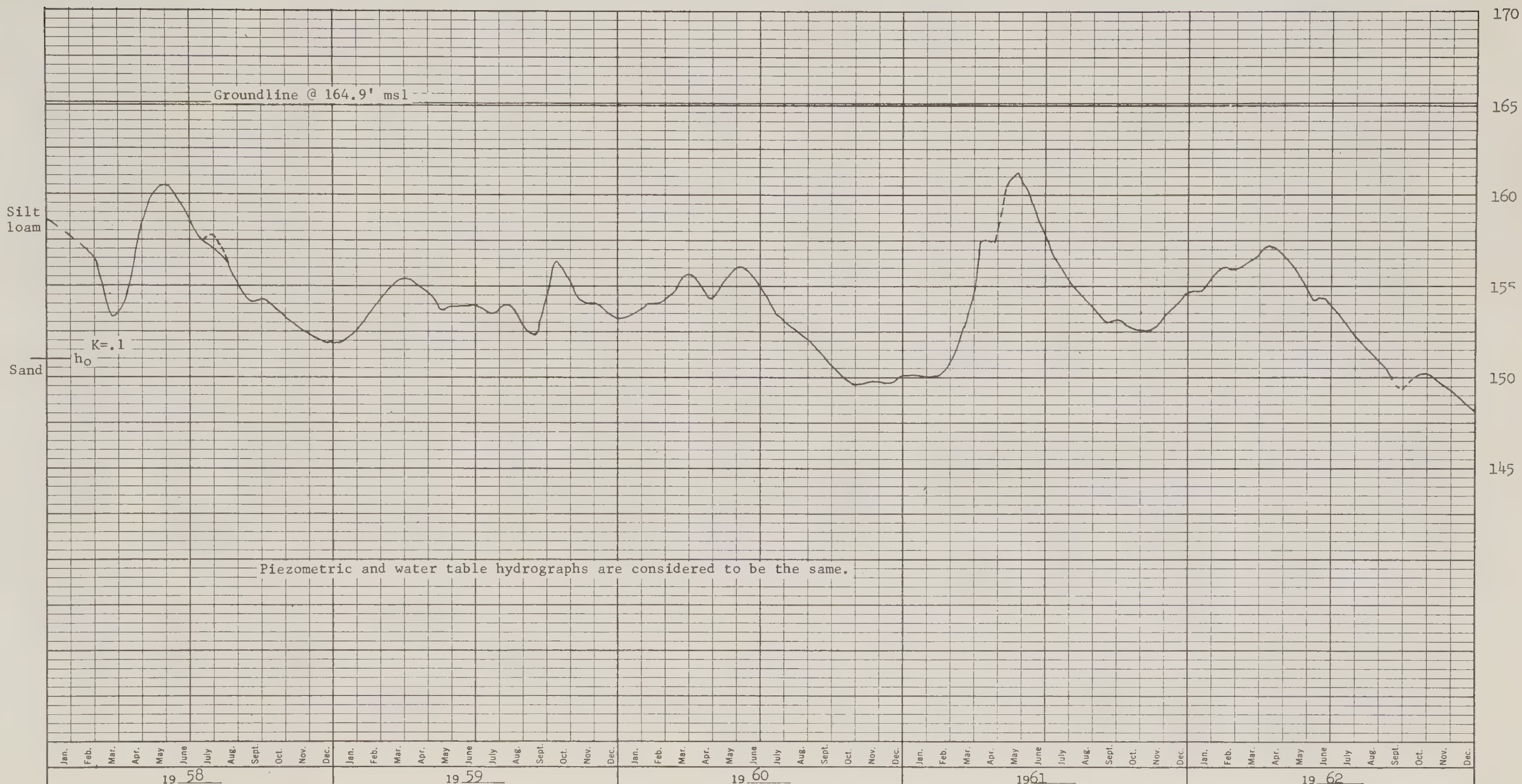

Figure 23. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
8S-3W-27ccc

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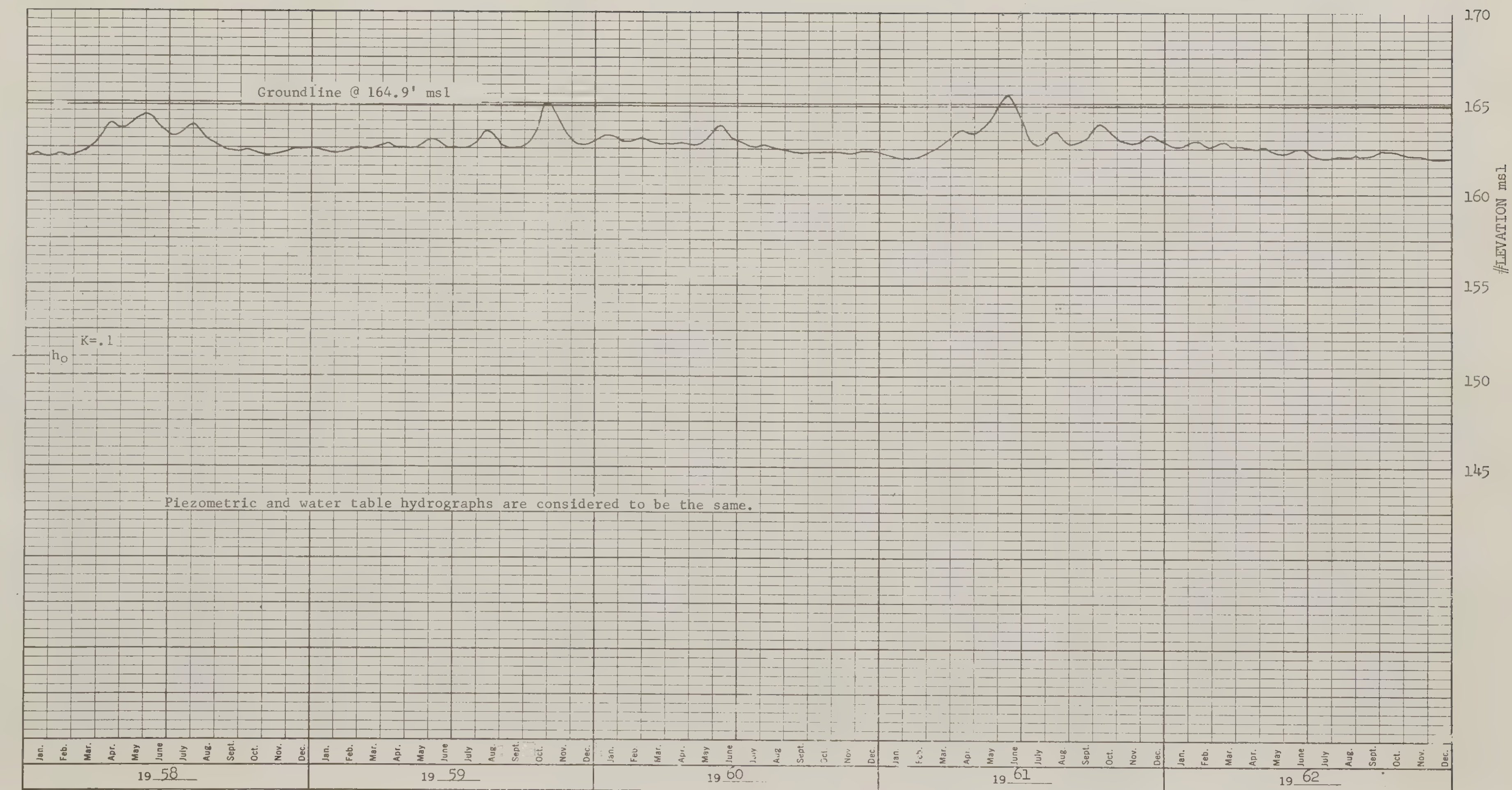

Figure 24. **WATER TABLE AND PIEZOMETRIC HYDROGRAPHS**

Post-Project

2S- 3W-27ccc

4-29630 6-70

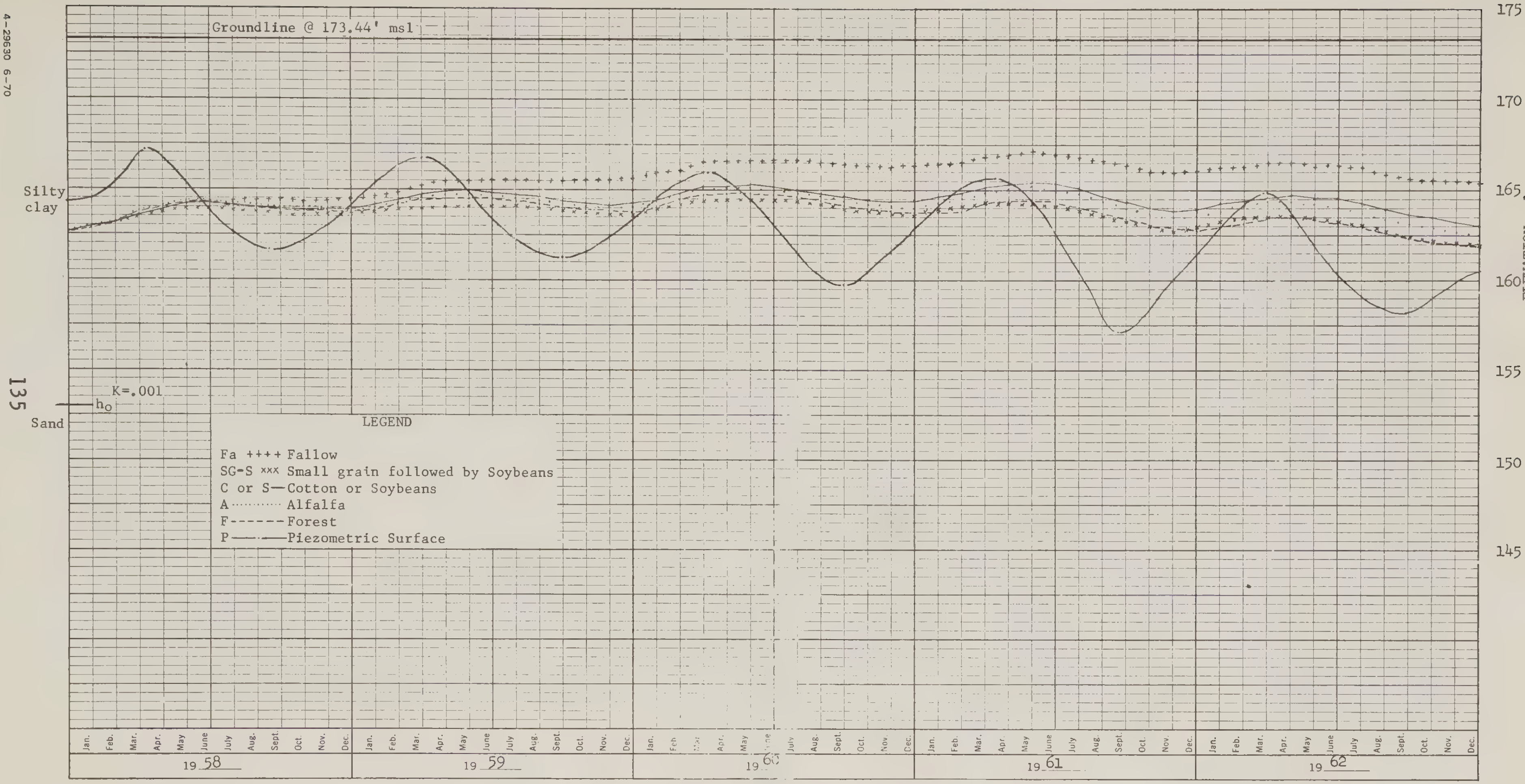

Figure 25. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
8S 4W-8bbb

4-29630 6-70

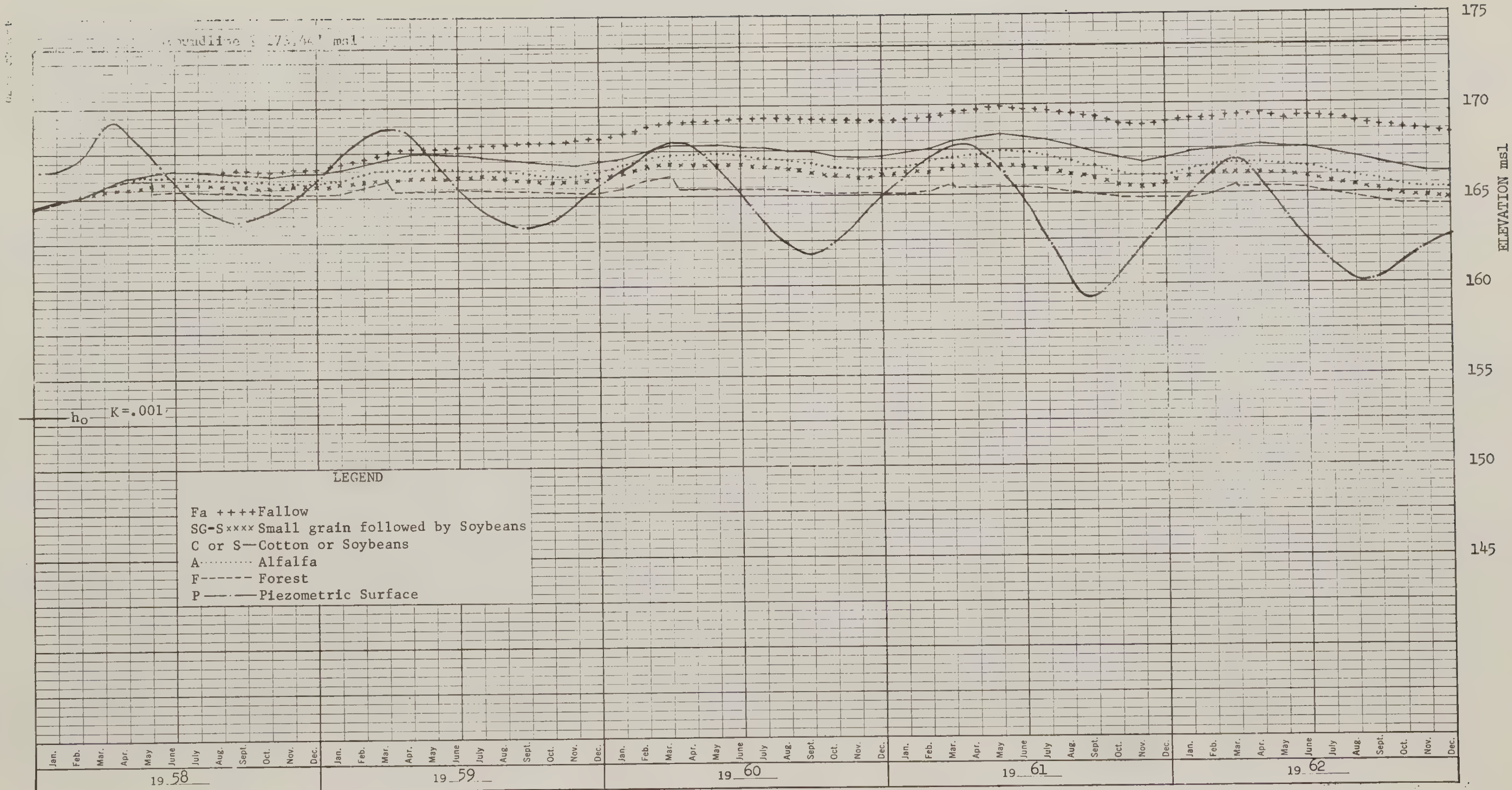

Figure 26. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
8S–4W–8bbb

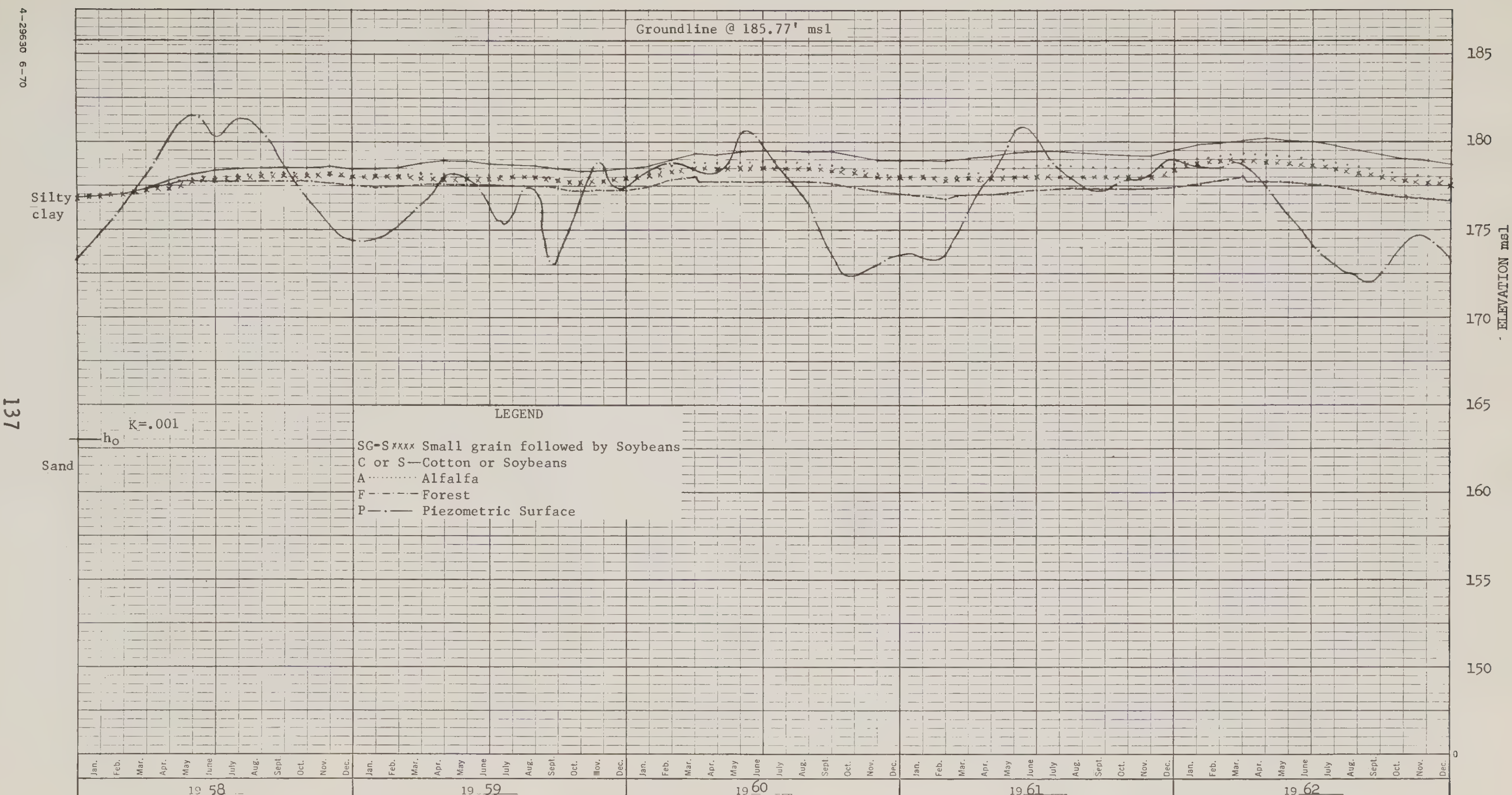

Figure 27. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
6S-6W-17dca

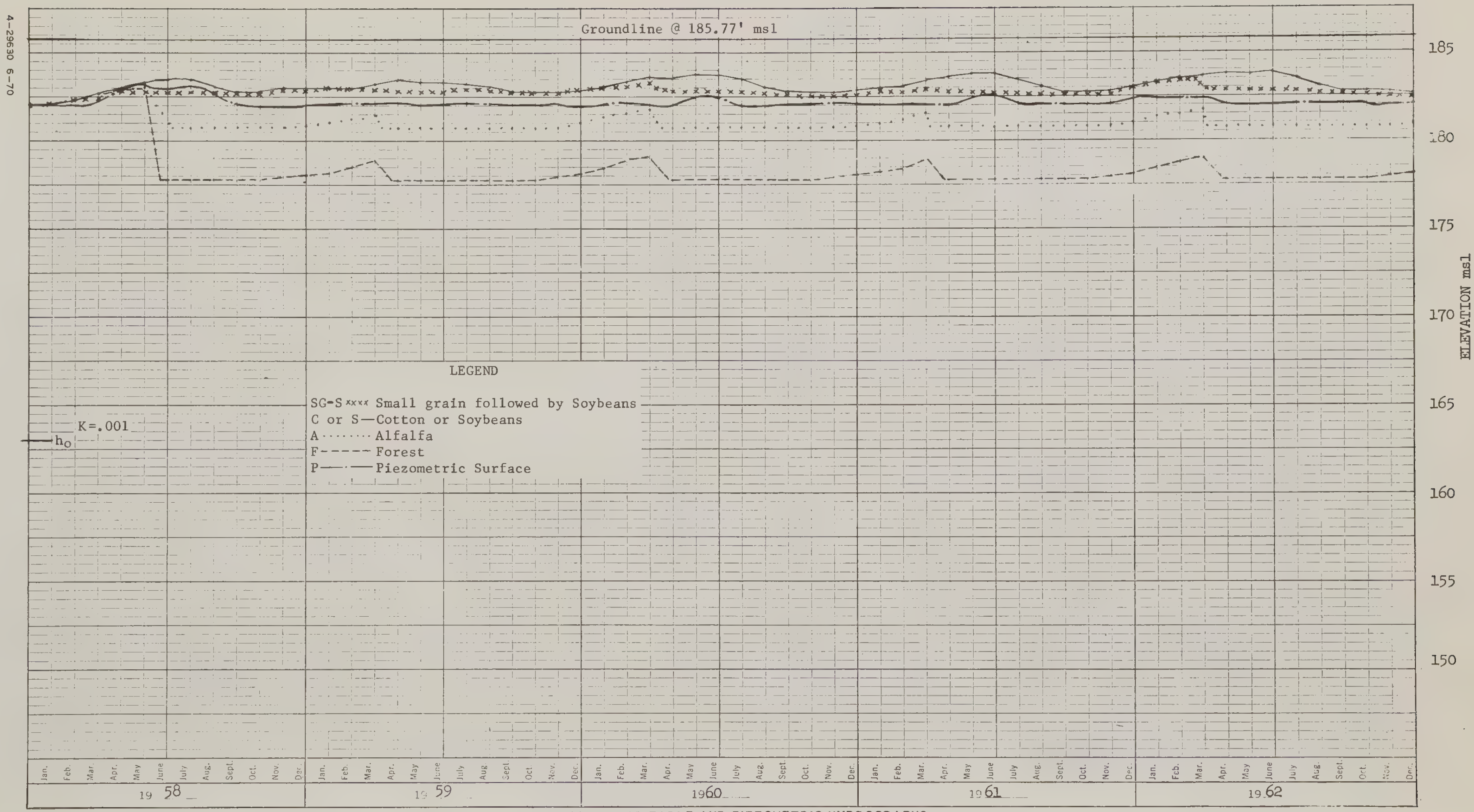

Figure 28. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
6S-6W-17dca

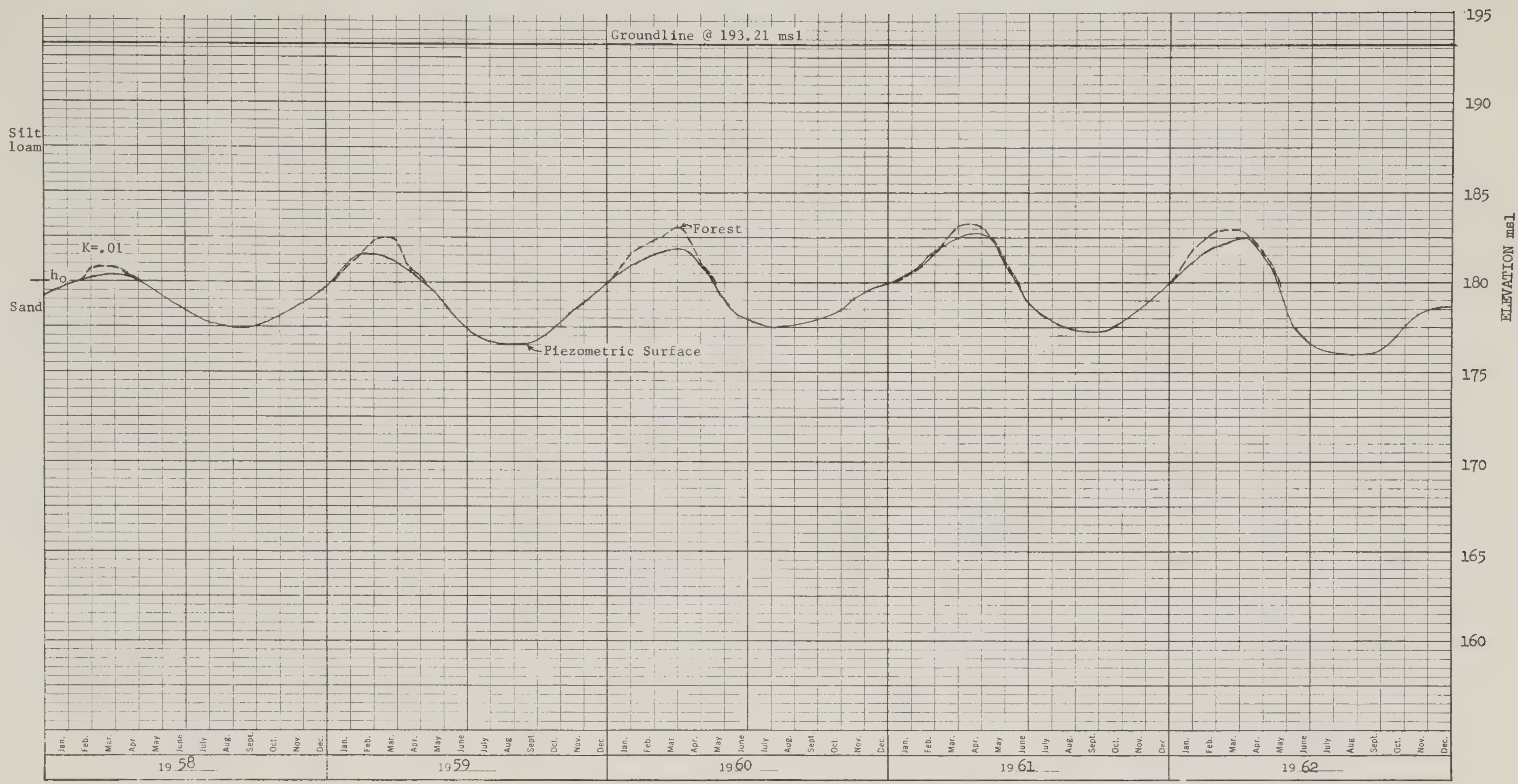

Figure 29. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
4S–7W–31ccb

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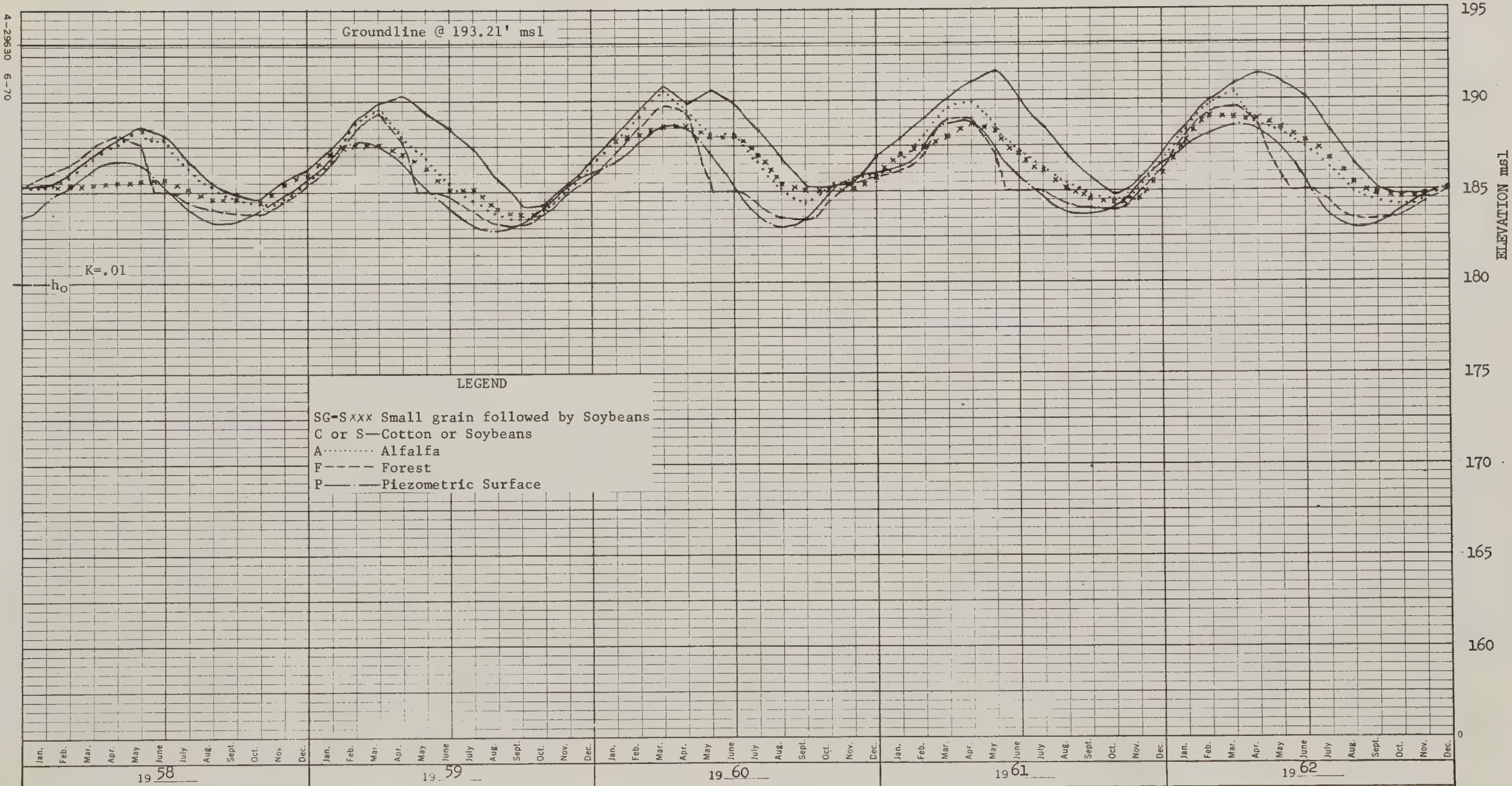

Figure 30. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
4S-7W-31ccb

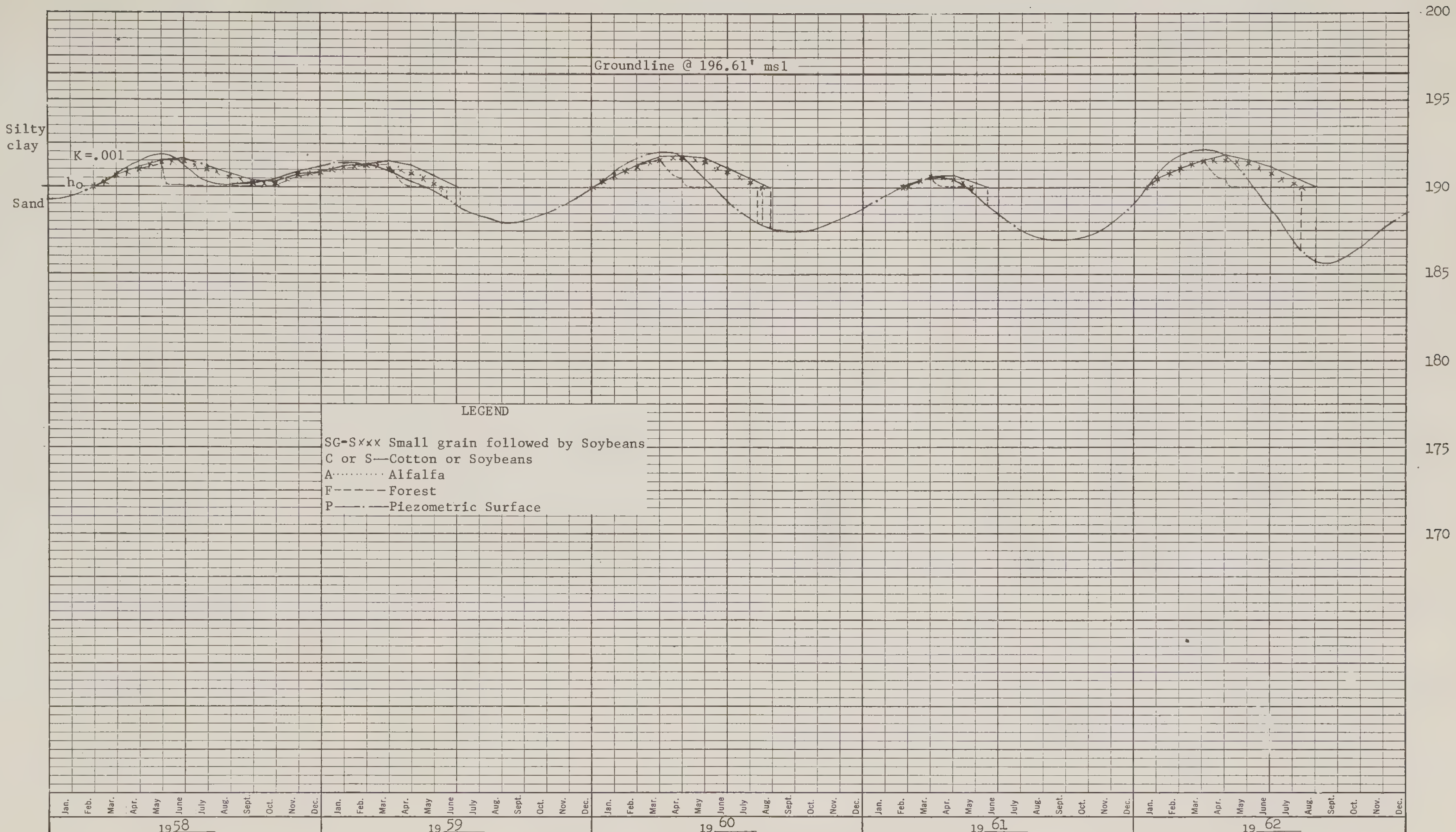

Figure 31. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
6S–8W–33bab

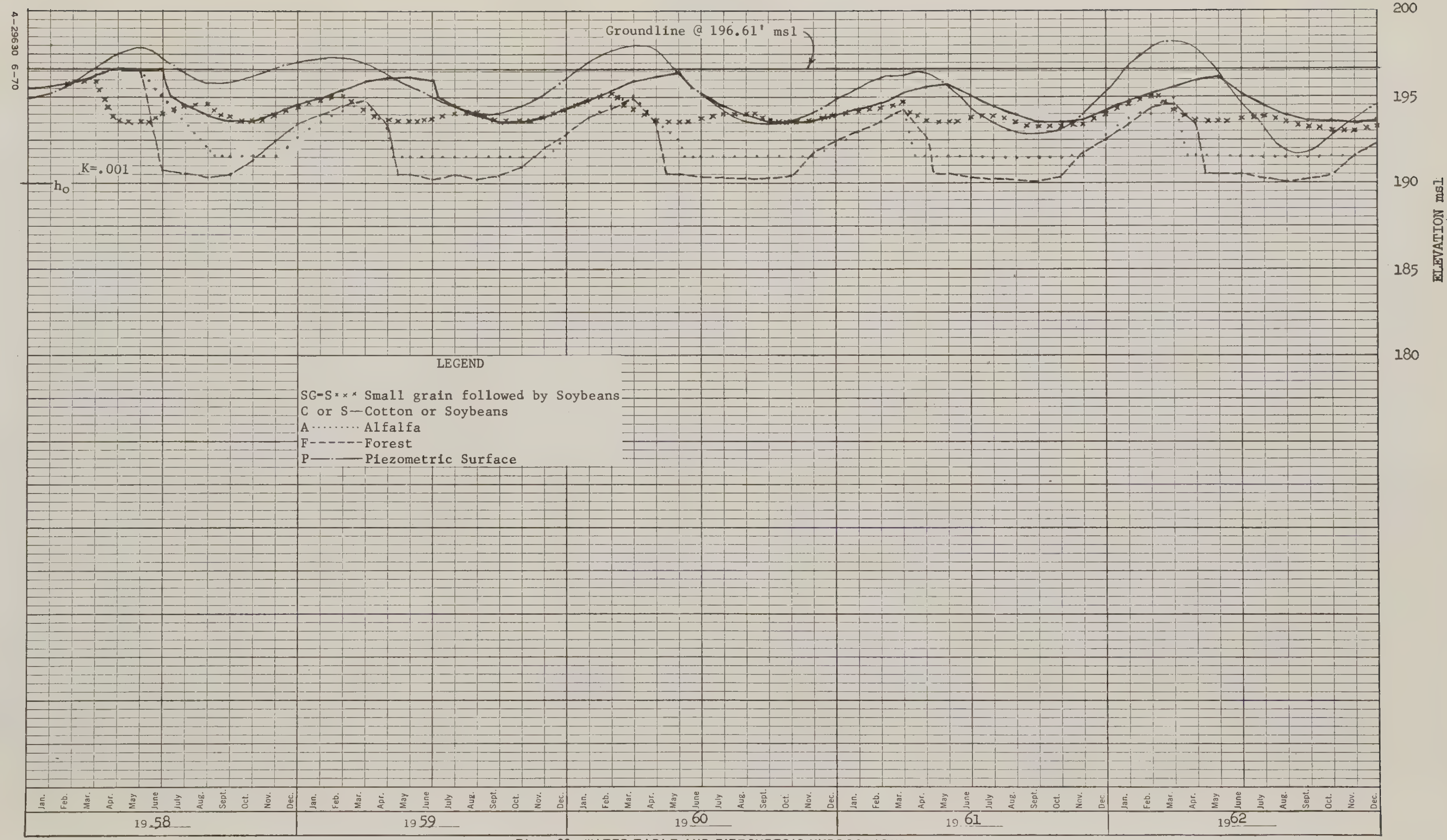

Figure 32. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
6S–8W–33bab

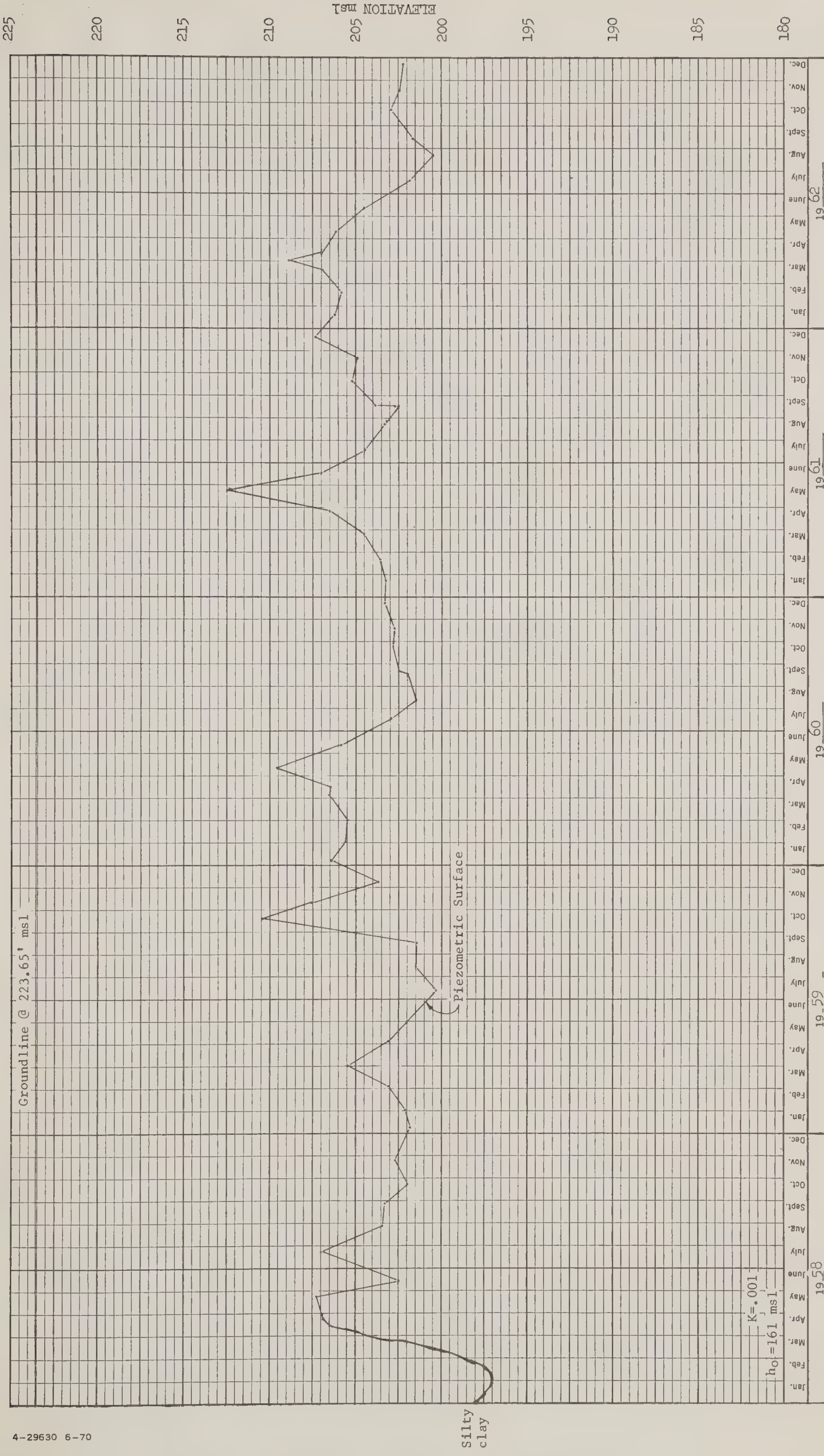

Figure 33. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
3S—10W—23bcc

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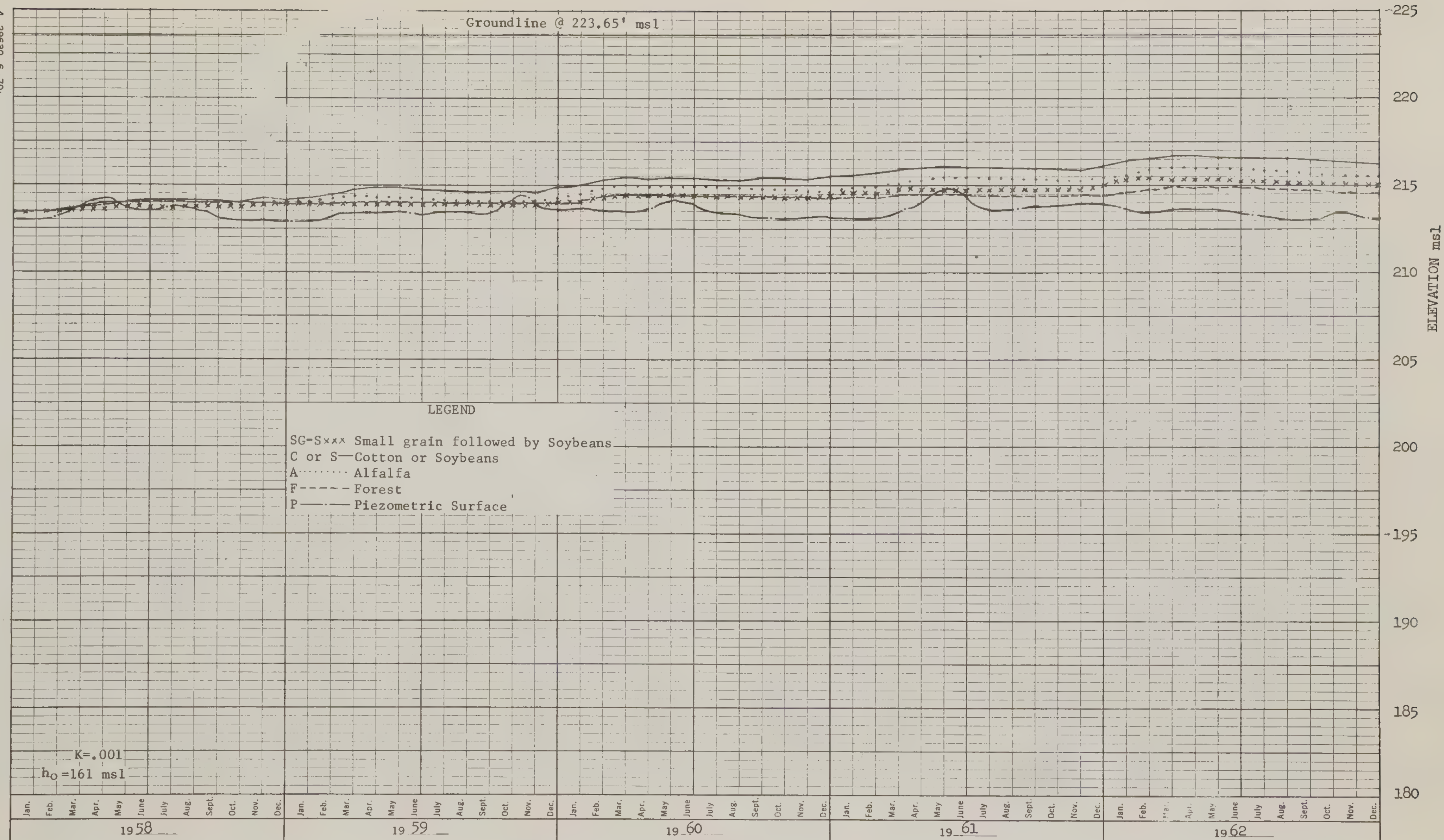

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Figure 34. **WATER TABLE AND PIEZOMETRIC HYDROGRAPHS**
Post-Project
3S-10W-23bcc

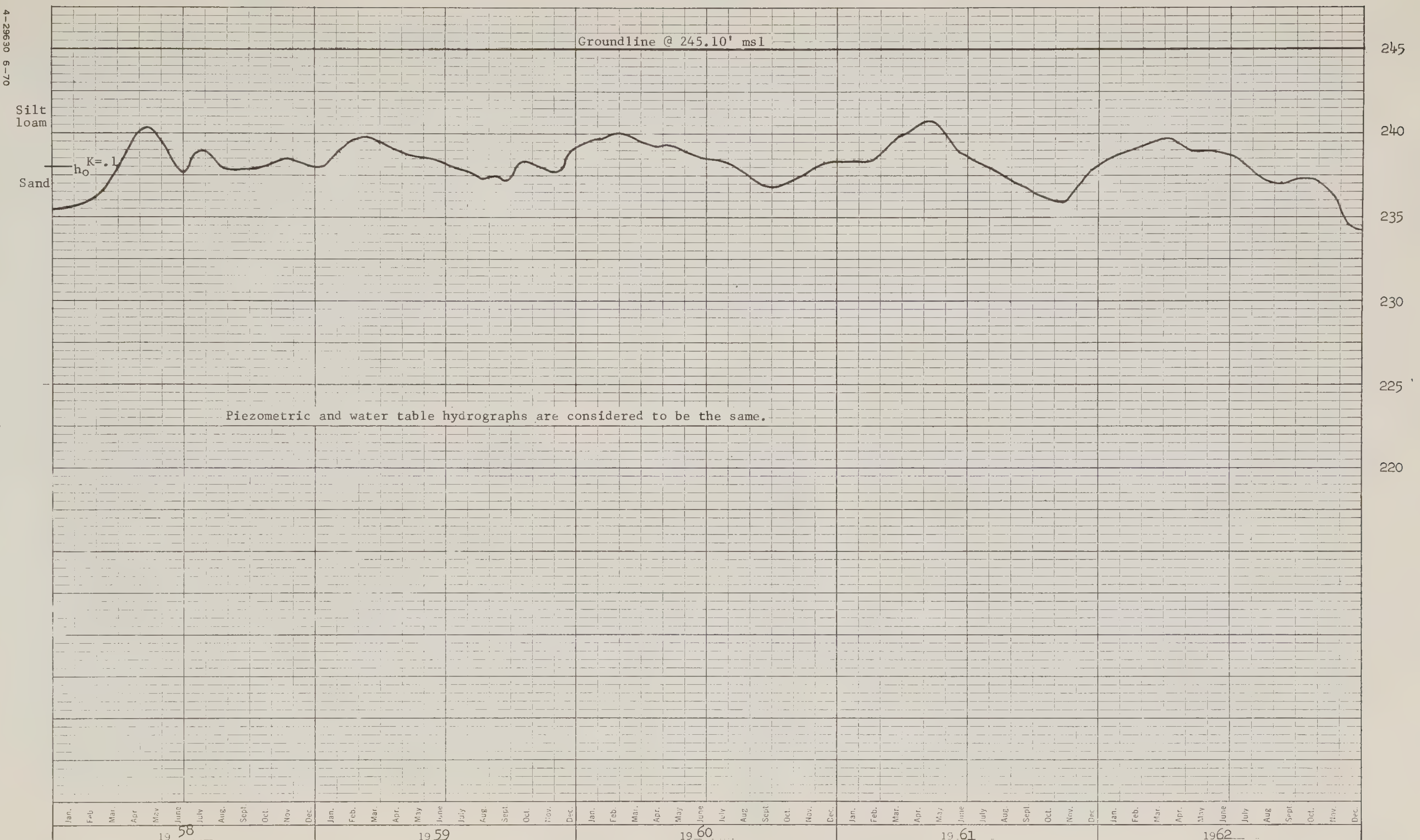

Figure 35. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
1N-11W-30abb

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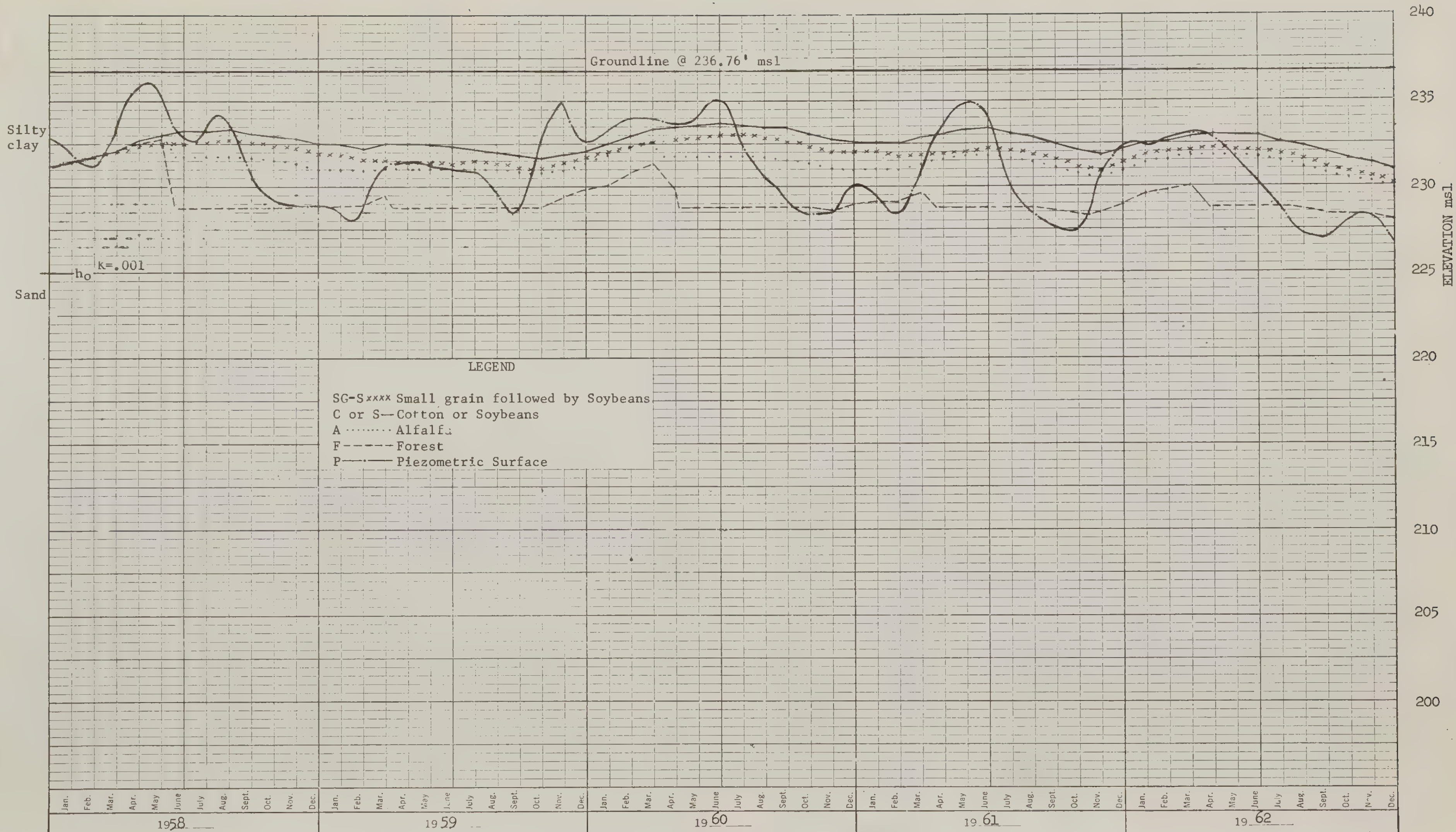

Figure 36. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
1S-11W-4add

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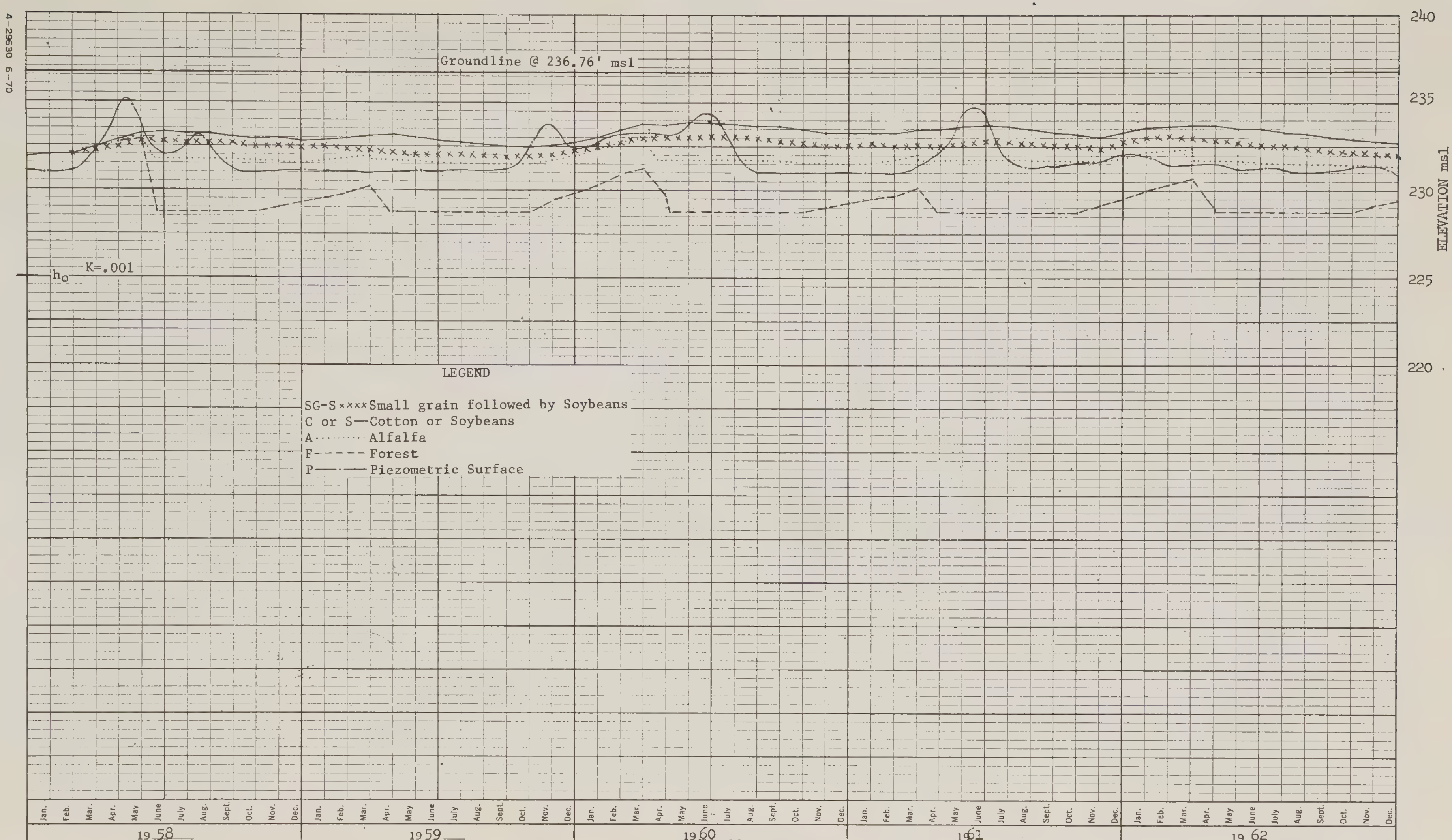

Figure 37. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
1S-11W-4add

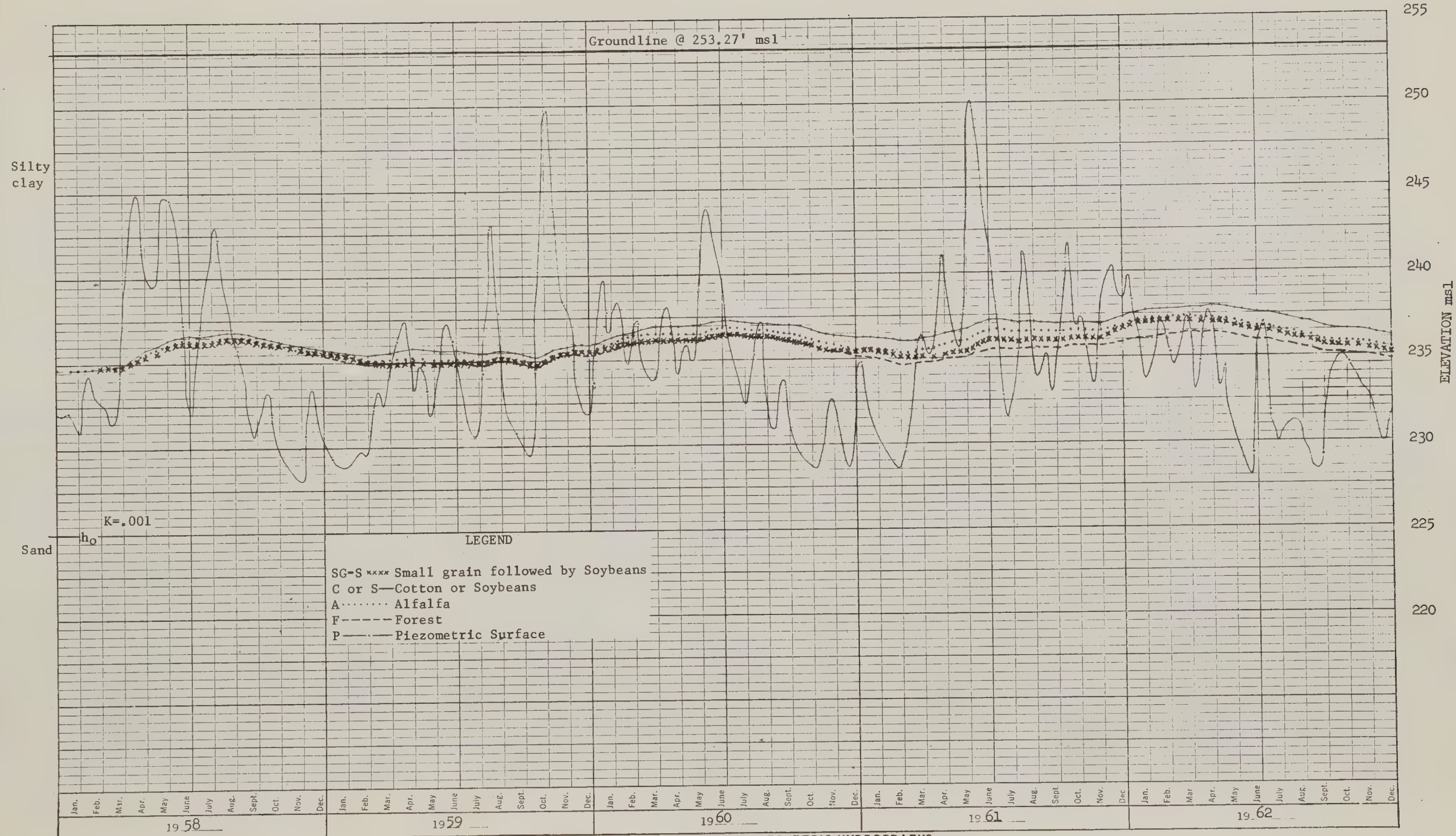

Figure 38. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
2N–13W–10cad

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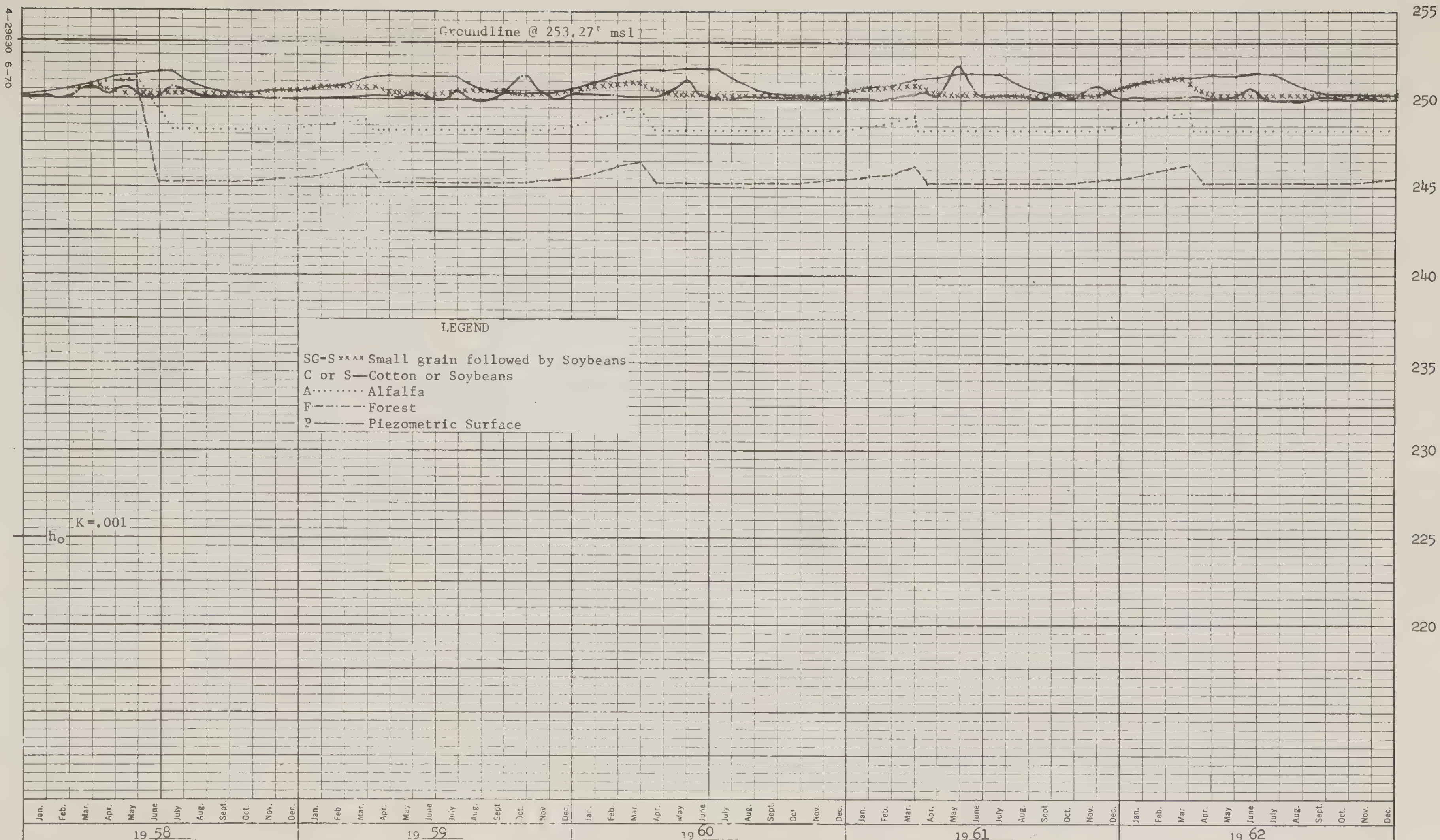

Figure 39. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
2N-13W-10cad

Figure 40. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
2N-13W-16bac

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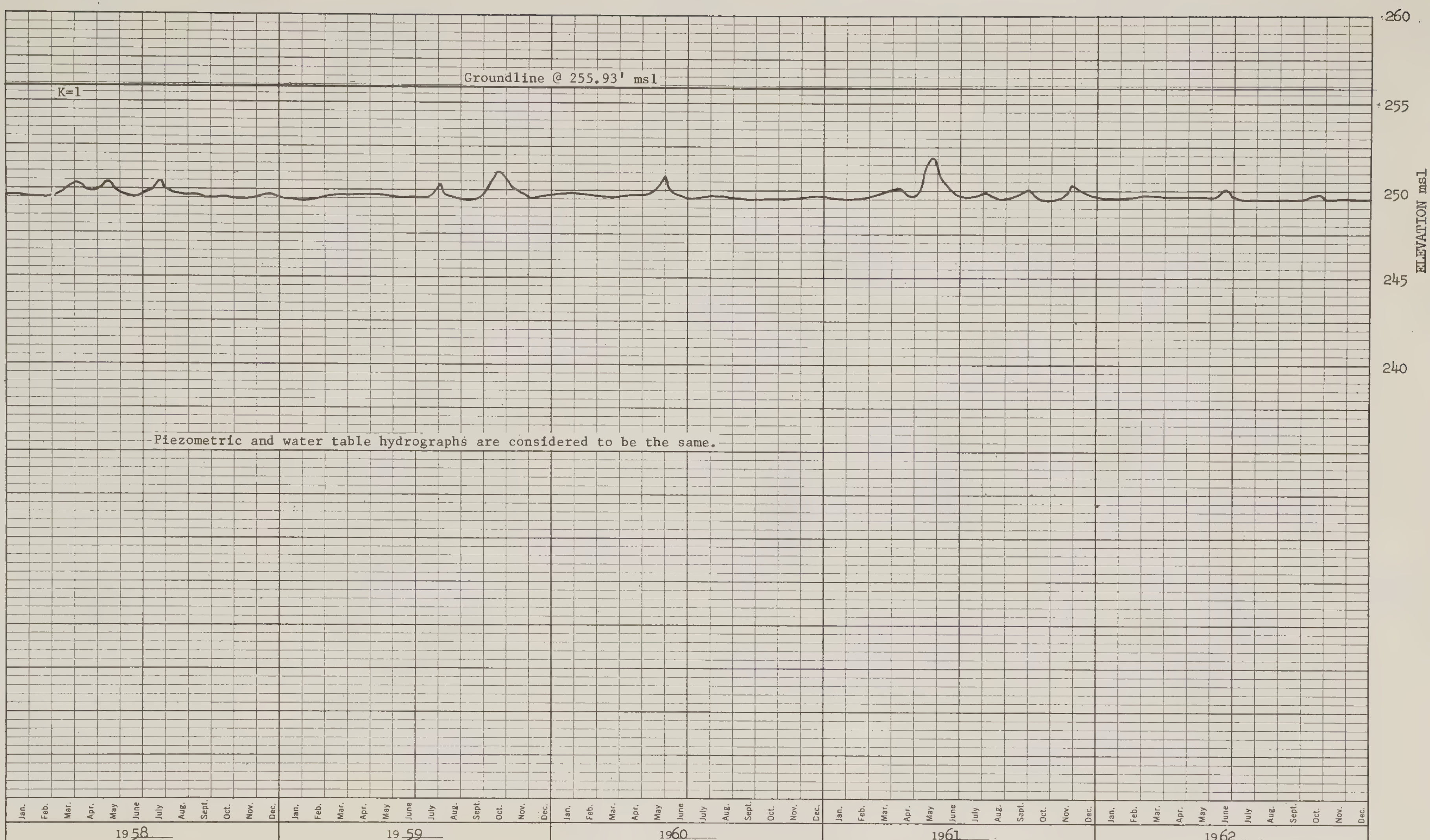

Figure 41. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
2N-13W-16bac

4-29630 6-70

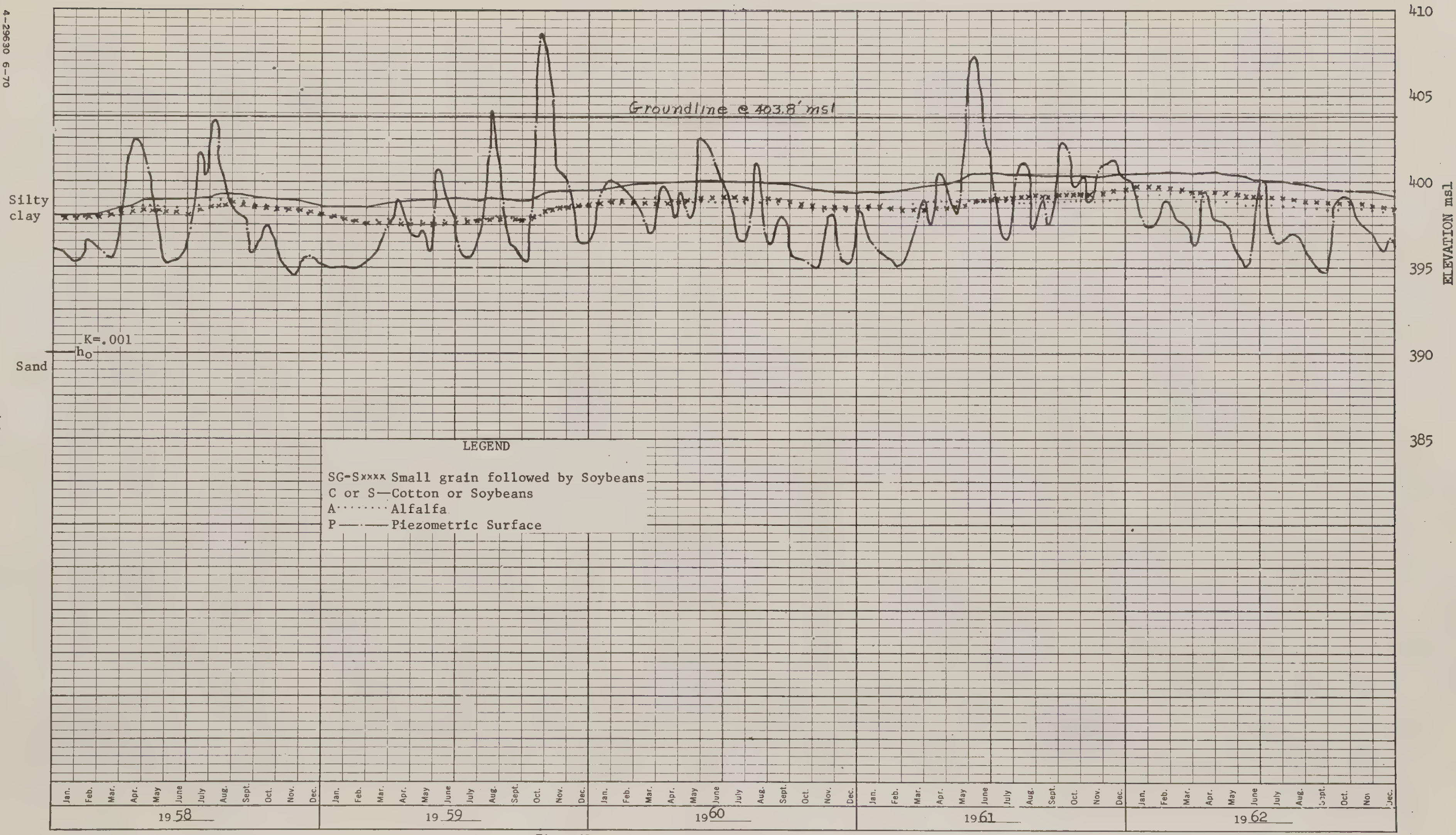

Figure 42. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
10N-27E-3cab

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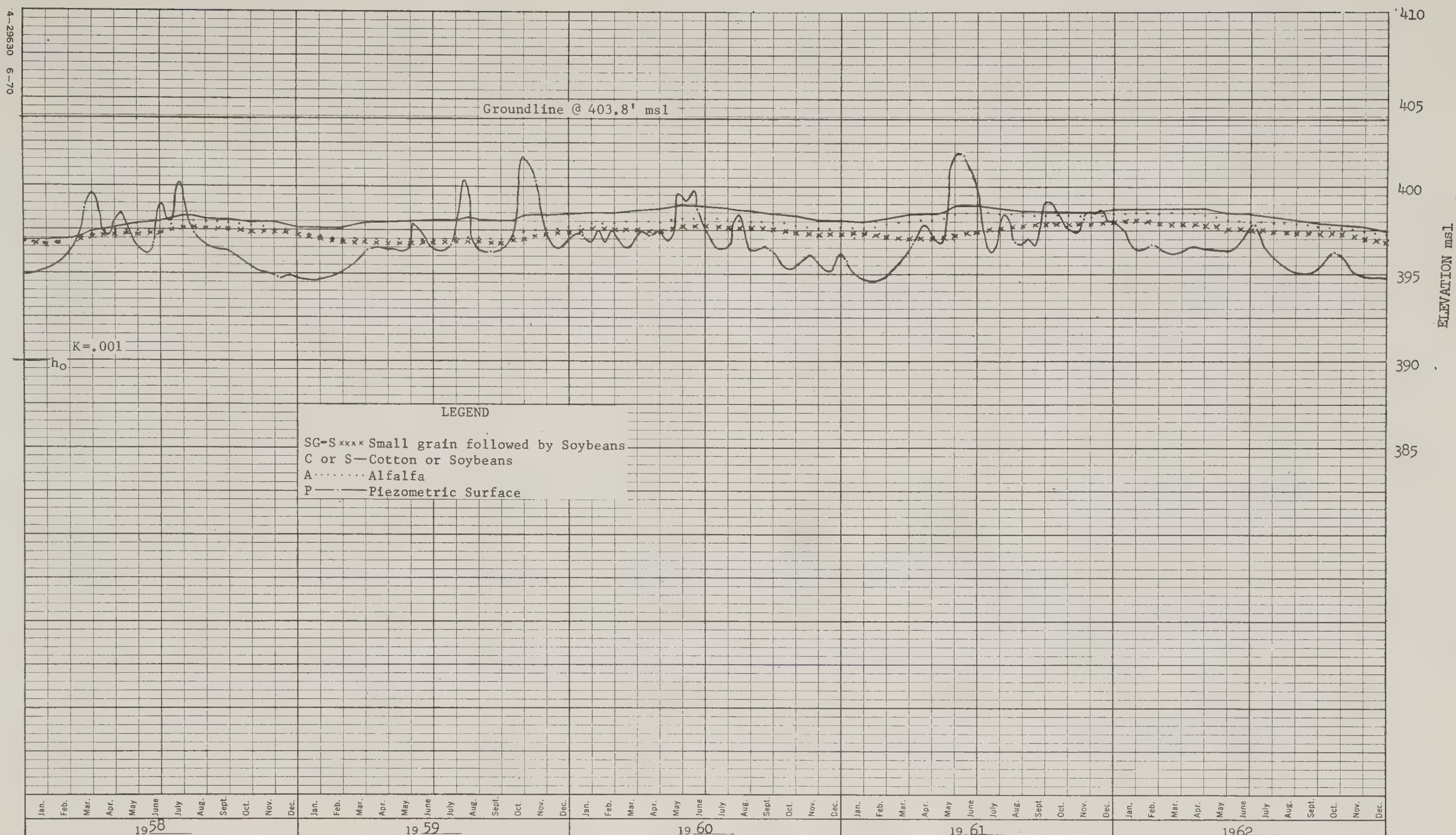

Figure 43. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
10N-27E-3cab

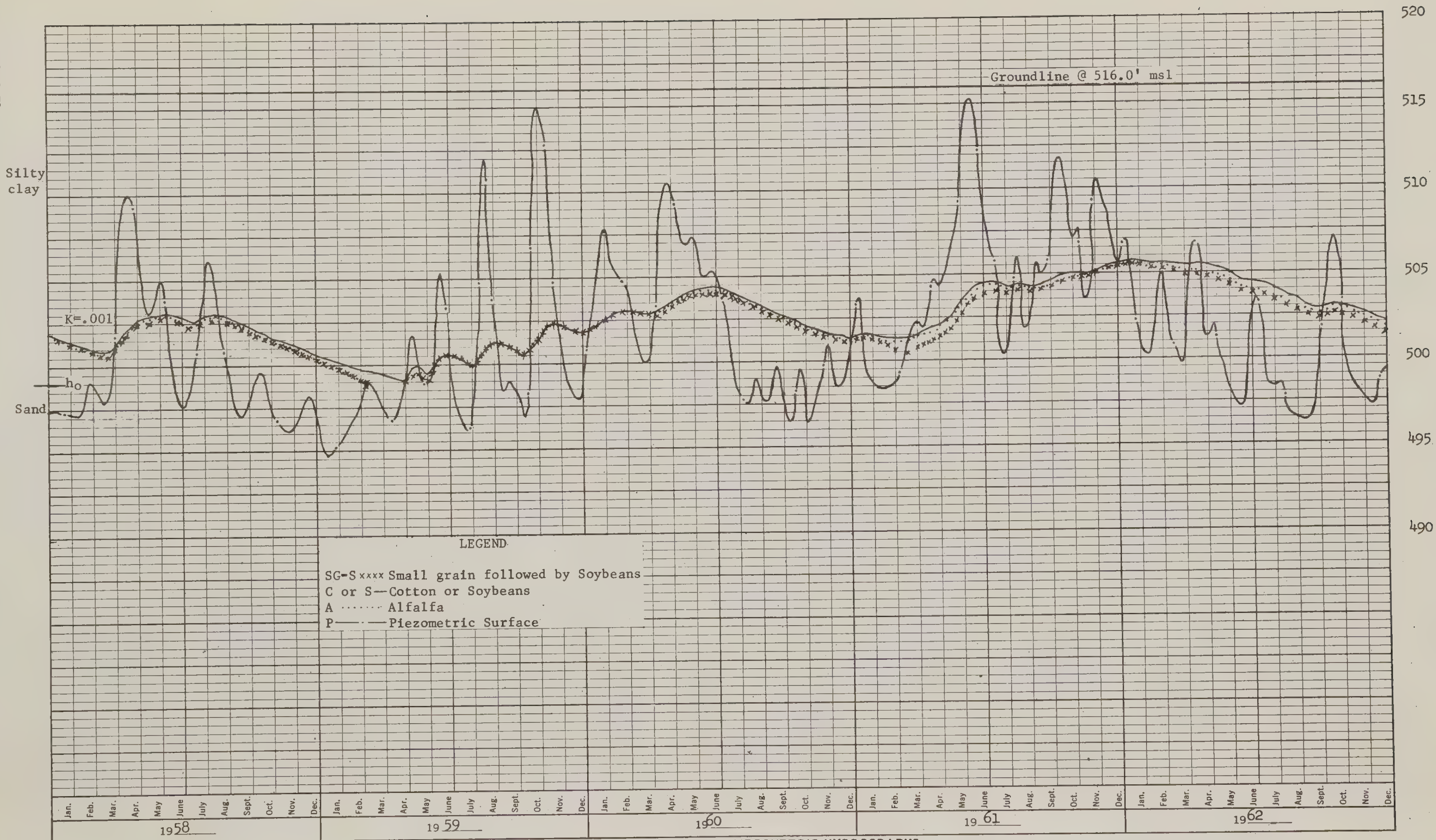

Figure 44. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
16N-18E-9bbb

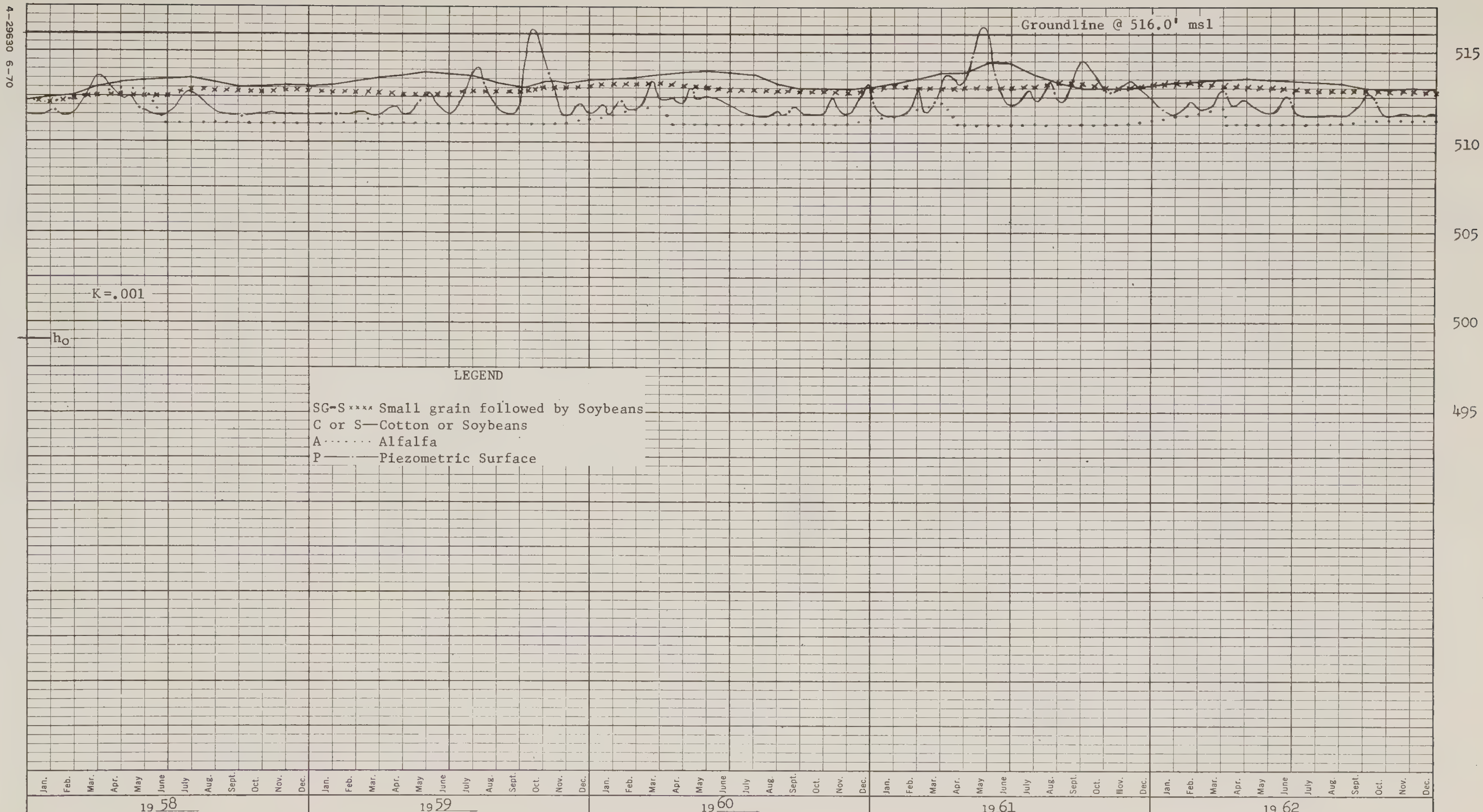

Figure 45. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
16N-18E-9bbb

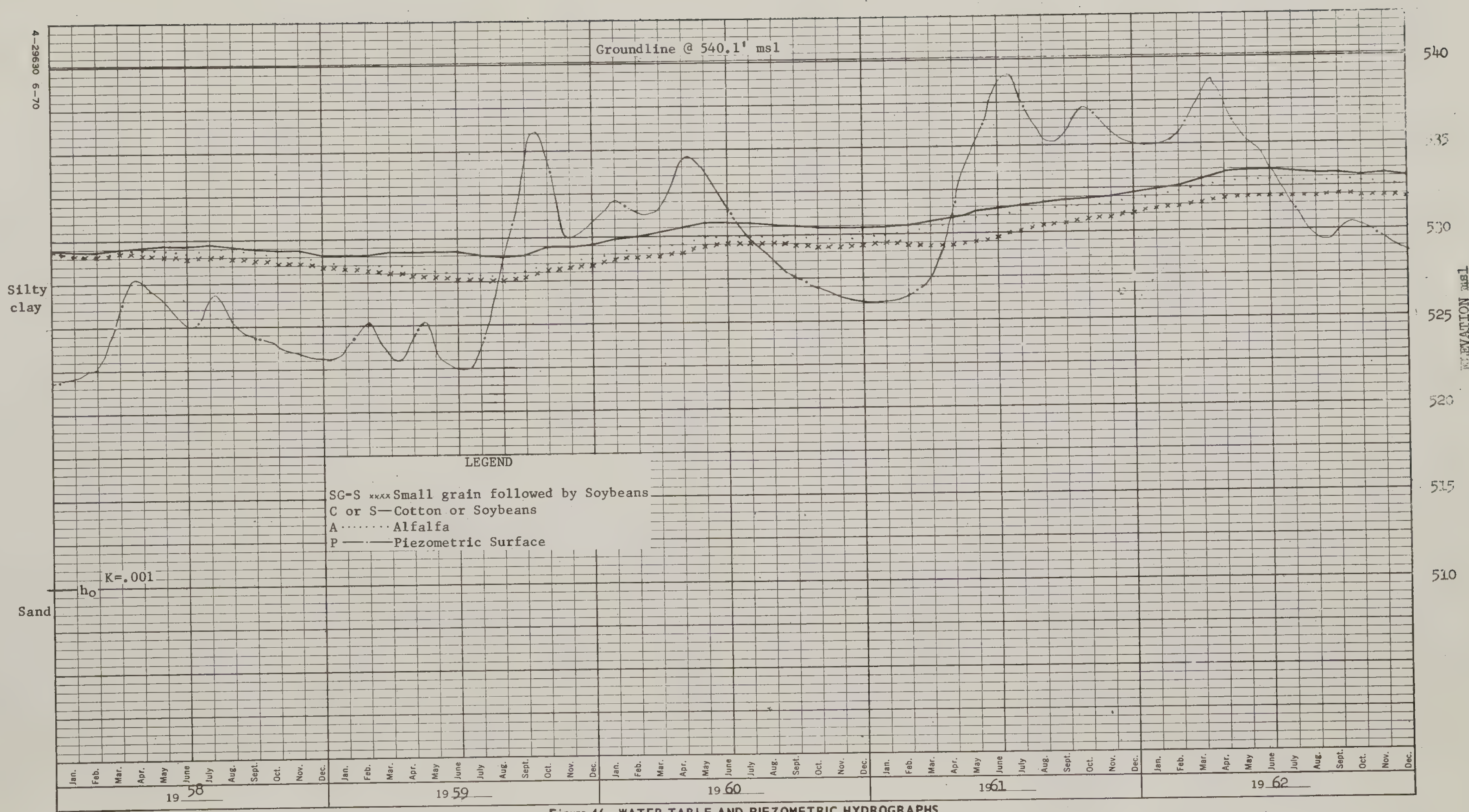

Figure 46. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Pre-Project
18N-16E-1aaa

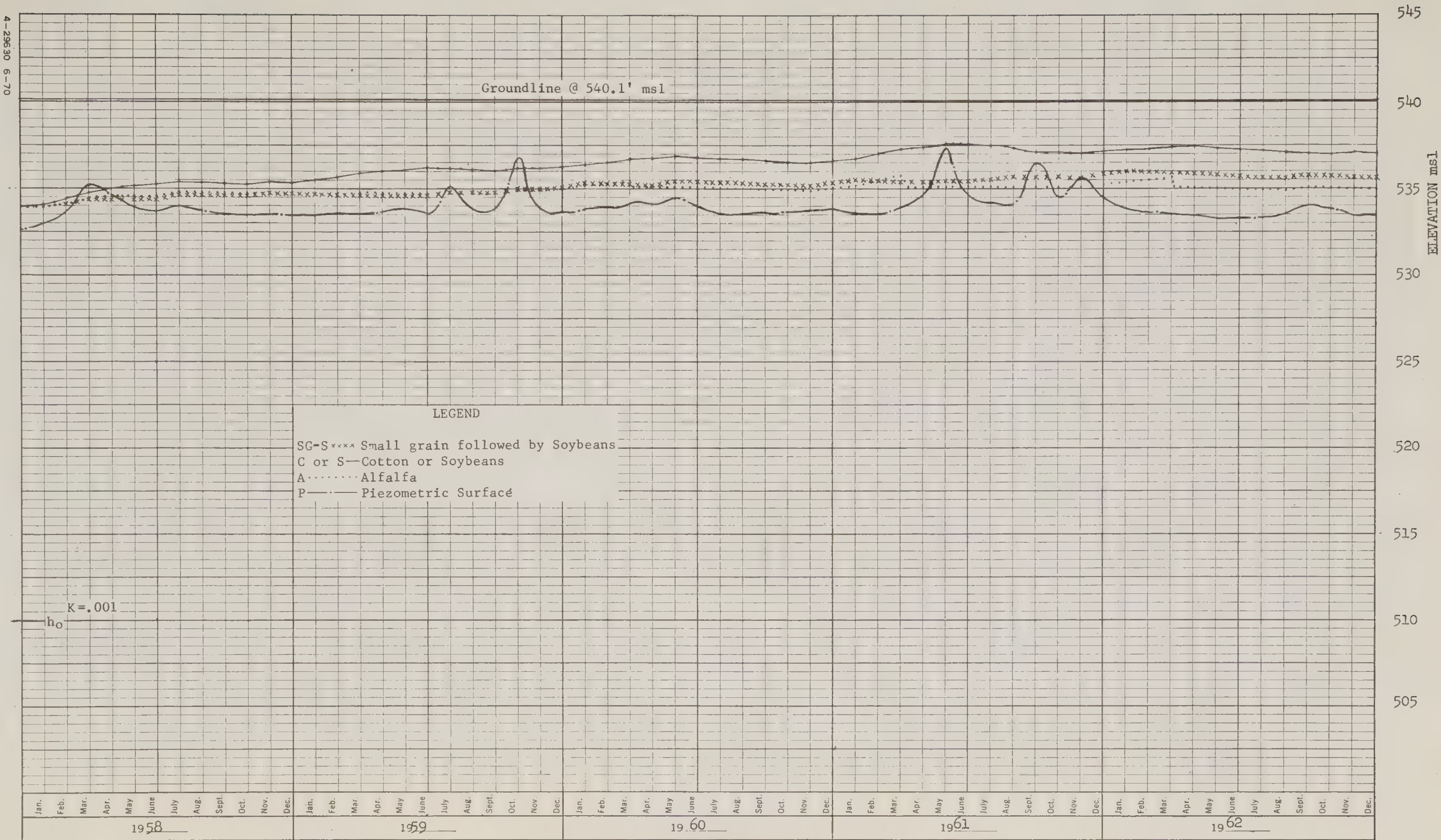

Figure 47. WATER TABLE AND PIEZOMETRIC HYDROGRAPHS
Post-Project
18N-16E-1aaa

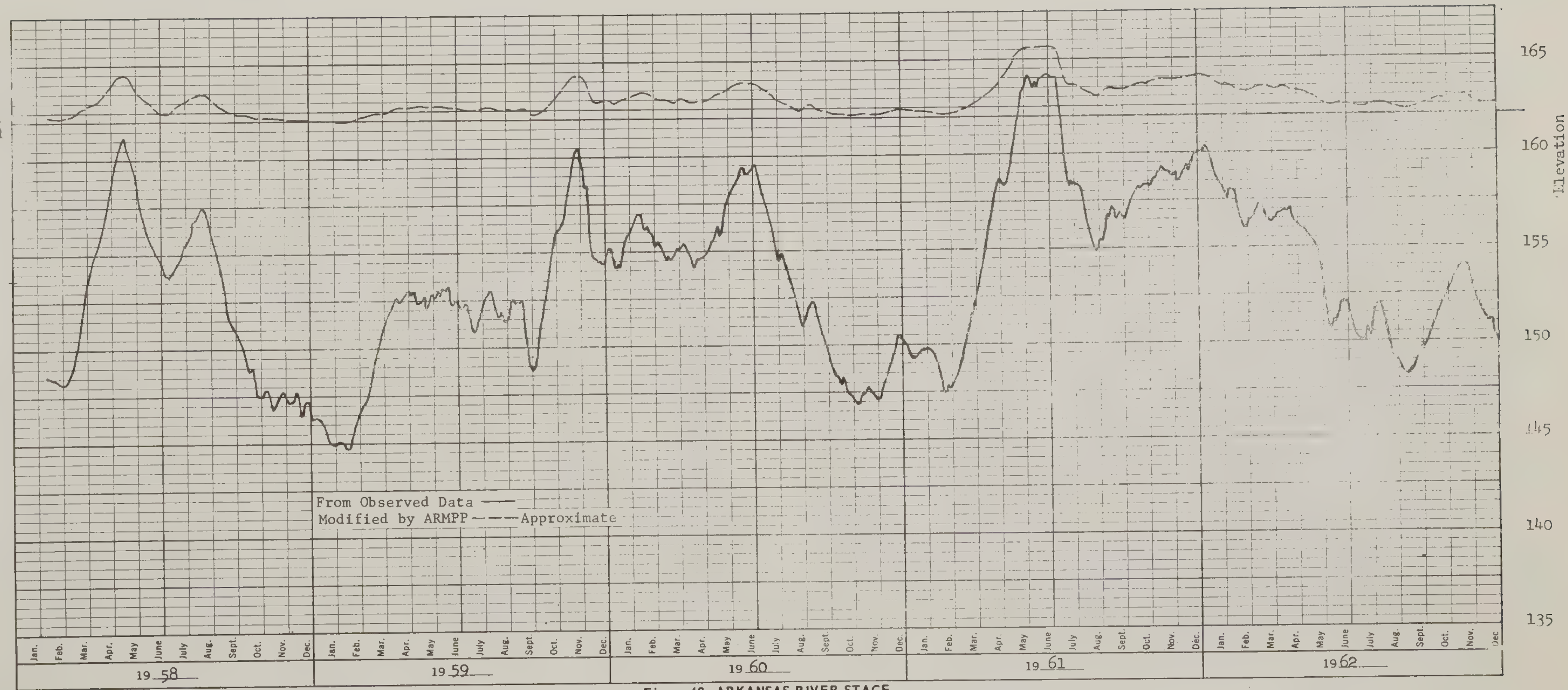

Figure 48. ARKANSAS RIVER STAGE
@ Project Mile 26.5
Based on Pendleton, Arkansas Gage
60-day Running Average

Figure 49. ARKANSAS RIVER STAGE
@ Project Mile 61.3
Based on Pine Bluff, Ark. Gage
60–day Modified

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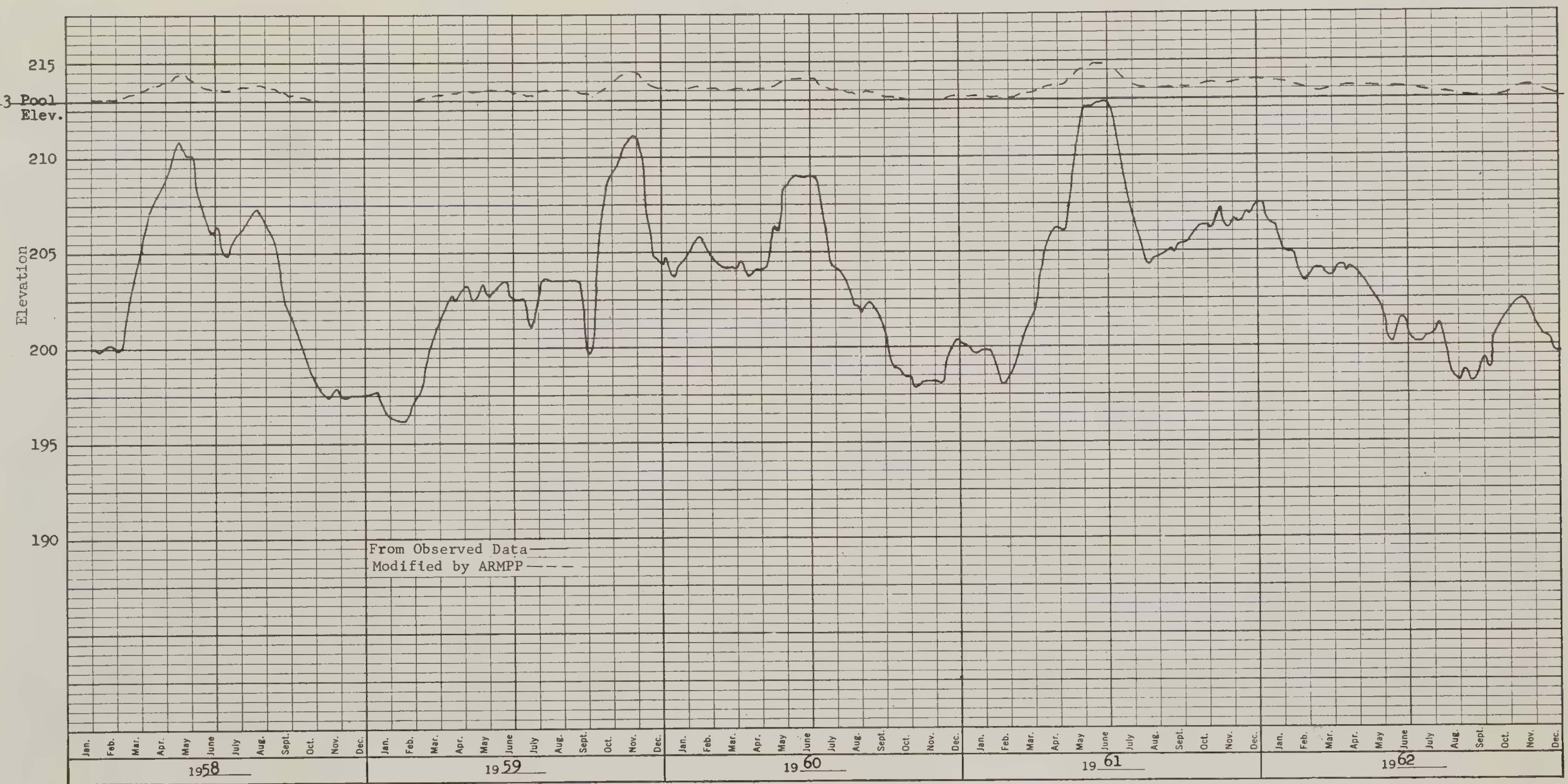

Figure 50. ARKANSAS RIVER STAGE
@ Brodie Bend P.M. 92.0
Based on USWB, Little Rock Gage
60-day Running Average (Mean Plotted at end)

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Figure 51. ARKANSAS RIVER STAGE
@ Little Rock, Arkansas USWB Gage
60-day Running Average (Mean Plotted at End)
Mouth of Fourche Creek P.M. 116.1

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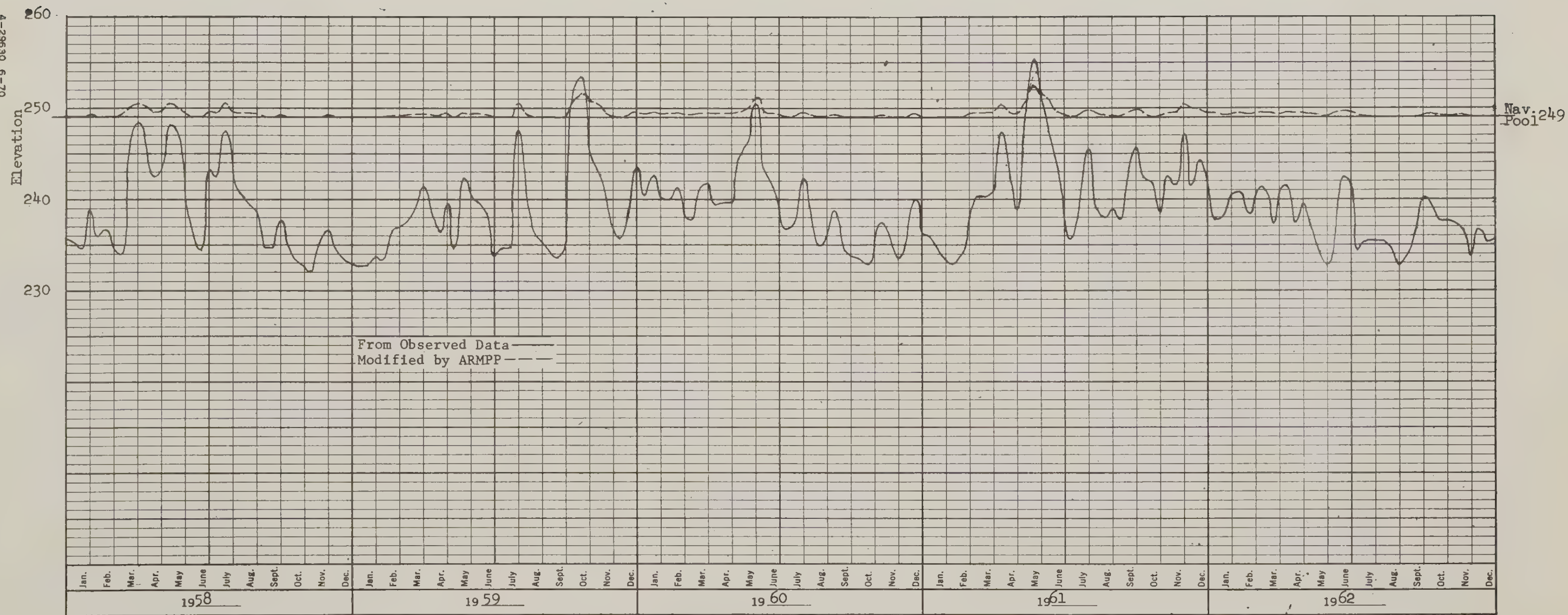

Figure 52. ARKANSAS RIVER STAGE
@USWB Gage, Little Rock, Ark.
Projected to P.M. 133.5
10-day Average

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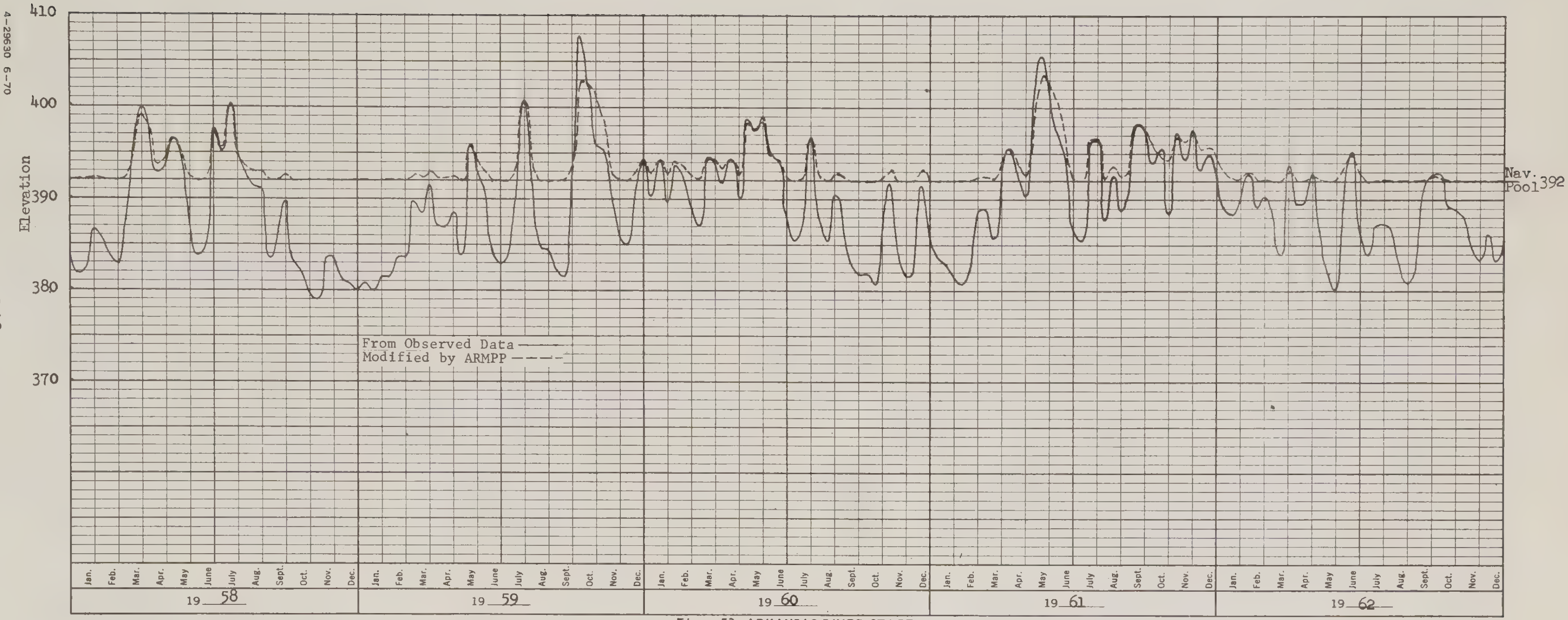

Figure 53. ARKANSAS RIVER STAGE
@USWB Gage, Van Buren, Ark.
Projected to 302.7 P.M.
10-day Average

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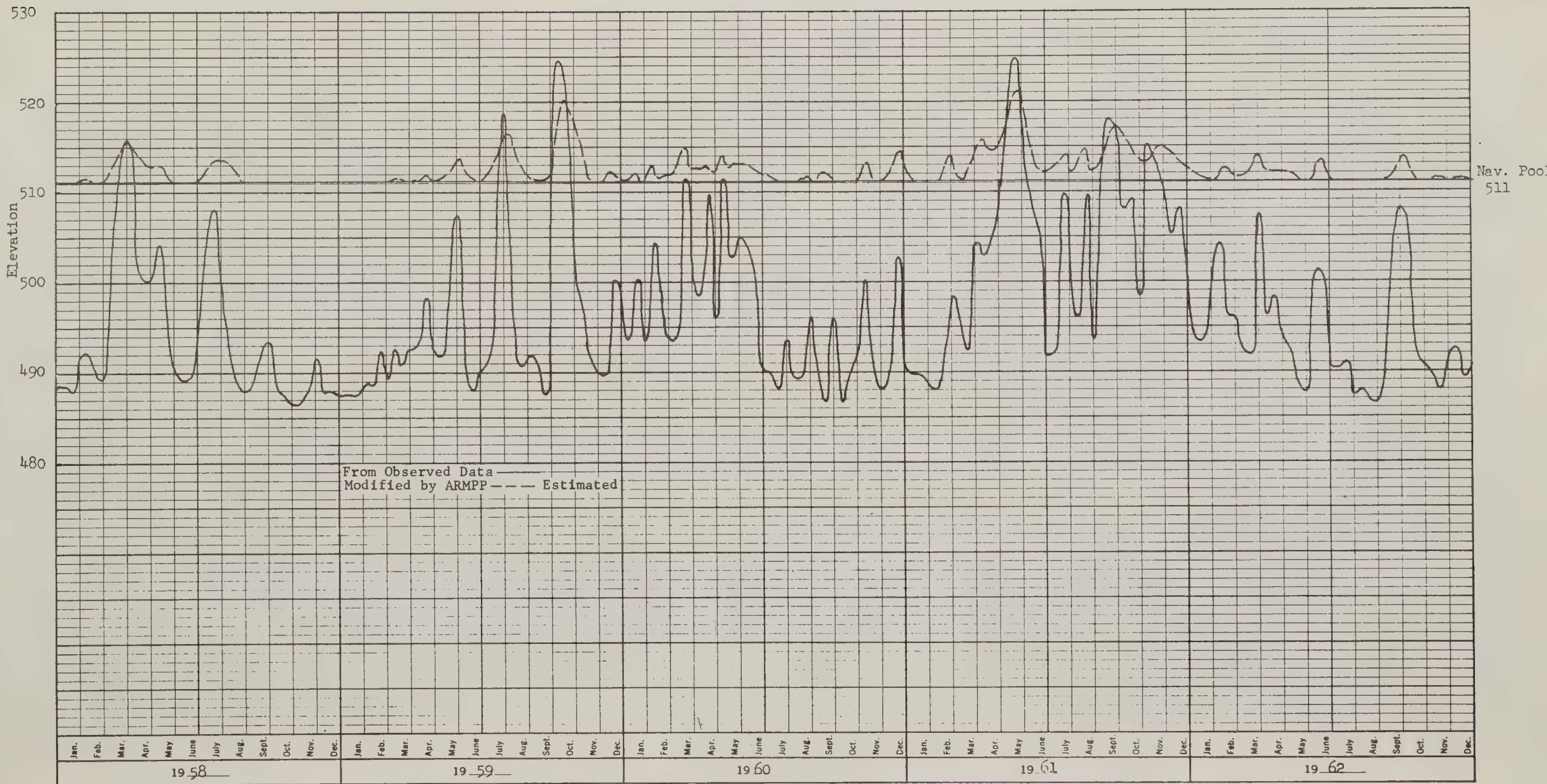

Figure 54. VERDIGRIS RIVER STAGE
@ USWB Gage, Inola, Okla.
Projected to P.M. 408.7
10–day Average

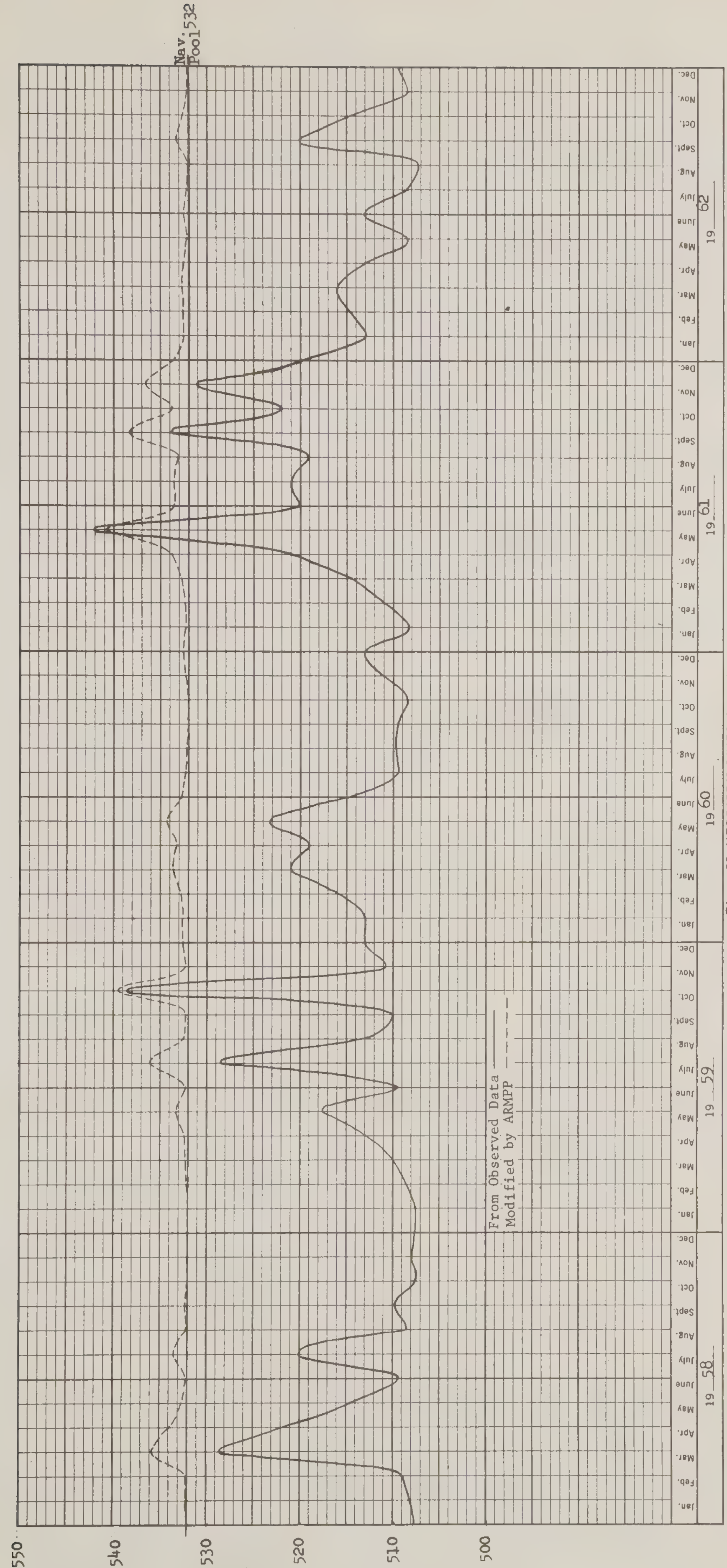

Figure 55. VERDIGRIS RIVER STAGE
@ USWB Gage, Inola, Okla.
Projected to P.M. 425.7
30-day Average

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LEGEND

Type of Study

Symbol	Description
A	Pre-project piezmeter data may or may not have been interpolated but no projection nor water table calculations made.
B	Water tables were calculated, both pre- and post-project, but there were no effects on crops.
C	Water table effects on crops.
D	Corps of Engineers easement or purchase.
•	Piezometer location in study area.
	Limit of USGS projected average piezometric surface. (below Little Rock, Ark.)
	Type of study boundary.
L&D 4	Lock and dam location.
PM 135.5	River and pool hydrograph location.

Figure 56

Sheet 1 of 6

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
TYPES OF STUDY AND PIEZOMETER LOCATIONS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

Rev. 6-70 4-R-29113

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USDA-SCS-FORT WORTH, TEX 1970

LEGEND

Type of Study

Symbol	Description
A	Pre-project piezmeter data may or may not have been interpolated but no projection nor water table calculations made.
B	Water tables were calculated, both pre- and post-project, but there were no effects on crops.
C	Water table effects on crops.
D	Corps of Engineers easement or purchase.
•	Piezometer location in study area.
——	Limit of USGS projected average piezometric surface. (below Little Rock, Ark.)
——	Type or study boundary.
L&D 4	Lock and dam location.
PM 135.5	River and pool hydrograph location.

N

1 0 1 2 3 4 MILES

APPROX SCALE 1:253,440

Figure 56

Sheet 2 of 6

ARKANSAS RIVER

MULTIPLE PURPOSE PROJECT STUDY AREA

TYPES OF STUDY AND PIEZOMETER LOCATIONS

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

LITTLE ROCK, ARKANSAS

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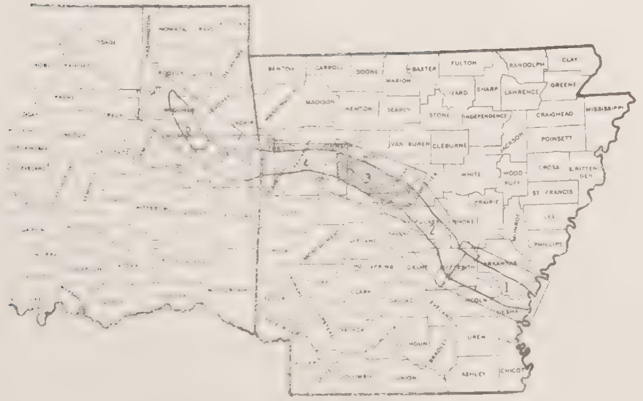


VICINITY MAP

LEGEND

Type of Study

Symbol	Description
A	Pre-project piezmeter data may or may not have been interpolated but no projection nor water table calculations made.
B	Water tables were calculated, both pre- and post-project, but there were no effects on crops.
C	Water table effects on crops.
D	Corps of Engineers easement or purchase.
•	Piezometer location in study area.
———	Limit of USGS projected average piezometric surface. (below Little Rock, Ark.)
———	Type of study boundary.
L&D 4	Lock and dam location.
PM 135.5	River and pool hydrograph location.

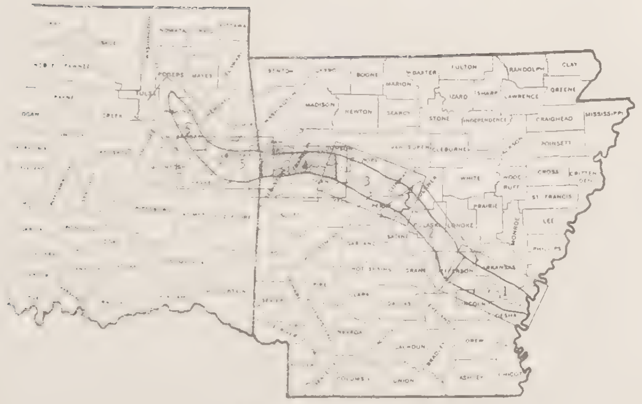
Figure 56

Sheet 3 of 6

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
TYPES OF STUDY AND PIEZOMETER LOCATIONS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

Rev. 6-70 4-R-29113



VICINITY MAP

LEGEND

Type of Study

Symbol	Description
A	Pre-project piezmeter data may or may not have been interpolated but no projection nor water table calculations made.
B	Water tables were calculated, both pre- and post-project, but there were no effects on crops.
C	Water table effects on crops.
D	Corps of Engineers easement or purchase.
•	Piezometer location in study area.
	Limit of USGS projected average piezometric surface. (below Little Rock, Ark.)
	Type or study boundary.
L&D 4	Lock and dam location.
PM 135.5	River and pool hydrograph location.

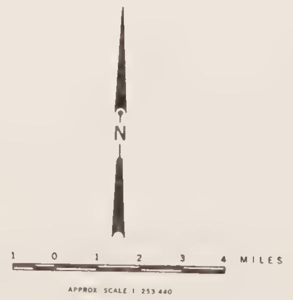
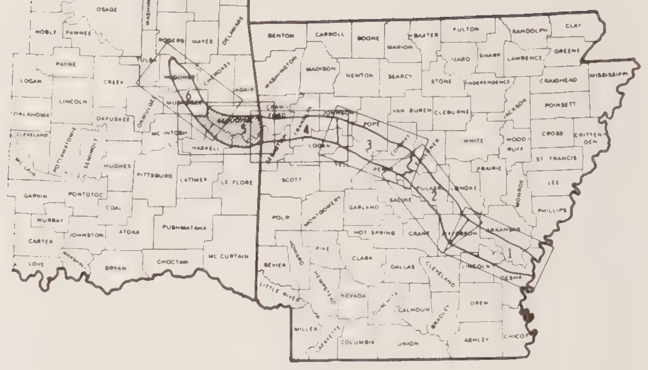


Figure 56

Sheet 4 of 6

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
TYPES OF STUDY AND PIEZOMETER LOCATIONS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS



N

1 0 1 2 3 4 MILES

APPROX SCALE 1:253 440

LEGEND

Type of Study

Symbol	Description
A	Pre-project piezmeter data may or may not have been interpolated but no projection nor water table calculations made.
B	Water tables were calculated, both pre- and post-project, but there were no effects on crops.
C	Water table effects on crops.
D	Corps of Engineers easement or purchase.
•	Piezometer location in study area.
	Limit of USGS projected average piezometric surface. (below Little Rock, Ark.)
	Type of study boundary.
L&D 4	Lock and dam location.
PM 135.5	River and pool hydrograph location.

Figure 56

Sheet 5 of 6

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
TYPES OF STUDY AND PIEZOMETER LOCATIONS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

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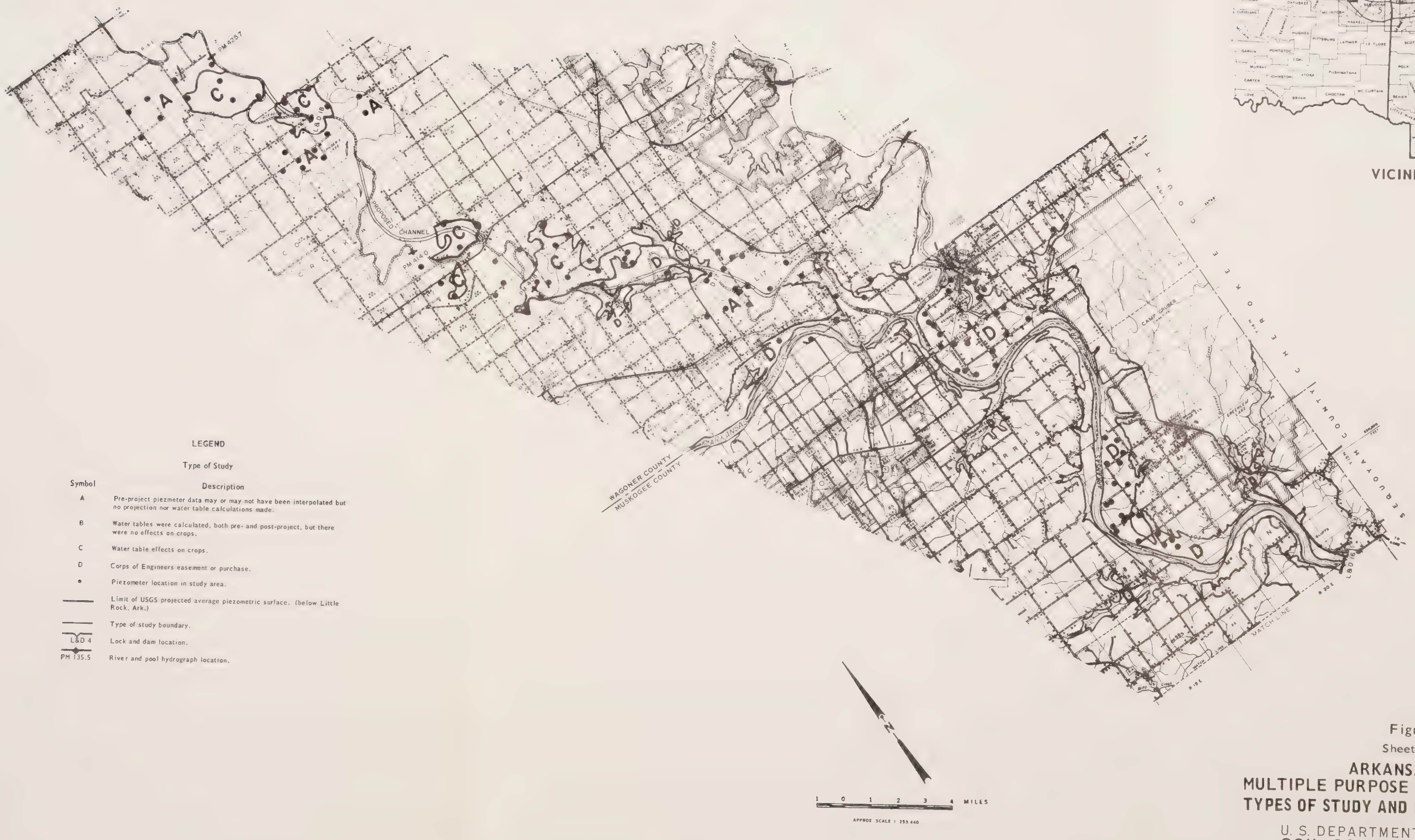

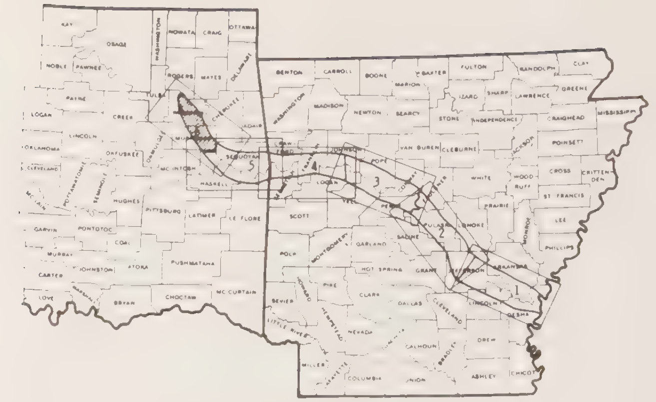

VICINITY MAP

LEGEND

Type of Study

Symbol	Description
A	Pre-project piezmeter data may or may not have been interpolated but no projection nor water table calculations made.
B	Water tables were calculated, both pre- and post-project, but there were no effects on crops.
C	Water table effects on crops.
D	Corps of Engineers easement or purchase.
•	Piezometer location in study area.
	Limit of USGS projected average piezometric surface. (below Little Rock, Ark.)
	Type of study boundary.
L&D 4	Lock and dam location.
PM 135.5	River and pool hydrograph location.

Figure 56
Sheet 6 of 6

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
TYPES OF STUDY AND PIEZOMETER LOCATIONS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

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production would be the same as if no water from the water table were available to the plants. A response of 150 indicates that production benefited from the water table and would be $1\frac{1}{2}$ times normal yield, 50 indicates damage from water table and production would be $\frac{1}{2}$ of normal, etc. The changes in response are the differences between the average pre-project responses and post-project responses of the crops and are percentage points. All of the response changes are shown on Figures 57 through 60 and are rounded to the nearest 25 percentage point change.

Figure 23, Page 133, shows a pre-project piezometric surface hydrograph with a silt loam above elevation 151 and with sand below elevation 151. The piezometric surface and water table are considered to be practically the same. Using the procedure of estimating crop response to water tables, it was determined that there would be no effect on cotton, soybeans, or small grain; however, alfalfa had a response of 125 in 1958 and 1961 and in the other years there was no effect. At the same location but under post-project conditions, Figure 24 shows the water table hydrograph. Under 1961 conditions, cotton planting would be delayed about six weeks which would result in no yield (Table 28) according to the crop response guide. However, the average of 5 years was 120, or an increase of 20 percentage points. The response of soybeans to these conditions resulted in a relative yield of 50. Small grain had no yield because of root damage by an invading water table at peak growth in May. Conditions as in 1962 were ideal for all the crops considered because the water table was between 2 feet and 3 feet deep during the entire year and Table 28 indicates a relative yield of 150 for all crops for that year. Alfalfa would die under conditions similar to May 1961 and no yield is indicated when these conditions exist. The net charge in yield for alfalfa and forest would be -5 and -20 percentage points under conditions of this 5 year period.

At location 8S-4W-8bbb (Figures 25 and 26, Pages 135 and 136) the piezometric surface fluctuates mainly from pumping of irrigation water. The water table is in fine textured material and its fluctuation is greatly dampened compared to the piezometric surface. Under pre-project conditions only the forest is affected and it was benefited. The piezometric surface was raised about 2 feet as a result of the ARMPP so that both alfalfa and forest are benefited under post-project conditions.

At 6S-6W-17dca (Figures 27 and 28, Pages 137 and 138) the piezometric surface fluctuates mostly from river and pool stage but the water table is influenced mostly by transpiration. Under pre-project conditions, only alfalfa and forest are affected because the water table is no shallower than 5 feet from the surface and is not deeper than 9 feet. The piezometric surface fluctuated 9 feet during the 5-year period but the water table fluctuated about 3 feet. Under post-project conditions the piezometric surface is near static pool stage with less than $1\frac{1}{2}$ feet fluctuation. The elevation of the water table is determined by the crop transpiration and rooting depth. These depths were about 3 feet for cotton, soybeans, and small grain; 5 feet for alfalfa; and 8 feet for forest. It was estimated that all crops would have relative yields of 150 under post-project conditions because of beneficial use of water from the water table.

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Post-project conditions at 4S-7W-31cbb (Figs. 29 and 30, Pages 139 - 140) show the relationship between water table and piezometric surface where the "K" value is 0.01 and the base of the finer textured material is about 5 feet below the average water table. At this location the benefits indicated are 15, 25, 45, and 50 percentage points for small grain, cotton or soybeans, alfalfa, and forest, respectively. This example also shows the effect of larger amounts of infiltration of rainfall reaching the water table because of the higher permeability value than the previous example. This caused the water table to be generally higher than the piezometric surface.

At piezometer 6S-8W-33bab (Figs. 31 and 32, Pages 141 to 142) the average piezometric surface was computed to raise 6 feet because of ARMPP. This caused the piezometric surface to be above the surface of the soil at times, resulting in water tables which delayed planting of cotton four out of five years with an average decrease in yield of 40 percentage points. The other crops benefited by the raised water table. The elevation of the water table during the growing season was dependent on transpiration and rooting depths of the plants.

At 3S-10W-23bcc (Figs. 33 and 34, Pages 143 and 144) the piezometric surface correlated closely with a 60 day average river and pool stage. The post-project pool stage and piezometric surface and water table hydrograph fluctuate only a few feet. The water table is so deep that only forest vegetation is influenced by it under post-project conditions.

At 1N-11W-30abb (Fig. 35, Page 145) the piezometric surface does not correlate with the river stage under pre-project conditions. To correlate the piezometric surface hydrograph elevation with river stage hydrographs would require unreasonable distances upstream from this location. The shape of the piezometric surface hydrograph generally correlates with the river stage hydrograph but elevations of the hydrographs do not correlate. To correlate these hydrographs under post-project conditions was impossible because the pool stage hydrograph would have had to be higher than the stages in pool 6. Static pool stage of pool 6 is about elevation 231. Fig. 35, Page 145, shows that the piezometric surface hydrograph generally fluctuated between elevation 235 and 240. It was considered that in situations like this the piezometric surface would not be affected by ARMPP because it is not affected by river or pool stage, but by other hydrologic factors.

About 3 miles southeast of the above location at 1S-11W-4add (Figs. 36 and 37, Pages 146 and 147) the pre-project piezometric surface hydrograph correlated well with the river stage hydrograph at P.M. 116.1 in both shape and elevation. The post-project piezometric surface hydrograph was developed to correlate similarly with post-project pool hydrograph at P.M. 116.1. Crops were benefited considerably under both pre- and post-project conditions so that changes in crop response from ARMPP were small.

At location 2N-13W-10cad (Figs. 38 and 39, Pages 148 and 149) the pre-project piezometric surface fluctuated more than 20 feet; however, most of this energy was dissipated through more than 10 feet of fine textured material and the calculated water table fluctuated less than 2 feet. Under post-project conditions the pool stage hydrograph was nearly constant at

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about elevation 250 and the calculated water table elevations resulted mostly from transpiration. There were no water table effects on crops under pre-project conditions but maximum benefits to all crops were realized under post-project conditions.

At 2N-13W-16bac (Figs. 40 and 41) piezometric surface hydrographs were similar to those at 2N-13W-10cad but the entire soil profile was sandy and the surface elevation is about 2½ feet higher in elevation. This resulted in only alfalfa and forest vegetation being benefited.

An example of where lowered water tables, because of ARMPP, reduced yields is shown at 10N-27E-3cab (Figs. 42 and 43). Under pre-project conditions the piezometric surface fluctuated between elevations 394 and 408 with water tables between elevations 398 and 401. Under post-project conditions the piezometric surface fluctuations were between elevations 395 and 403 with water tables between elevations 397 and 399. All crops benefited under pre-project conditions, but only alfalfa under post-project conditions.

At location 16N-18E-9bbb (Figs. 44 and 45) the piezometric surface hydrograph fluctuated 20 feet under pre-project conditions and 5 feet under post-project conditions. The corresponding river and pool stage fluctuations were 39 feet and 10 feet. Crops were not affected by the water table under pre-project conditions, and all crops had estimated increased yields of 50 percentage points.

At location 18N-16E-1aaa (Figs. 46 and 47) the piezometric surface correlated generally with the 30 day average river stage. The peaks occurred at about the same time and elevation except the piezometric peak in the spring of 1962. The water tables under pre-project conditions had no affects on the crops but under post-project conditions it was estimated that the water table would benefit each of the crops.

The above hydrographs, used as examples for this report, show most of the types of conditions in the study. They show piezometric surfaces fluctuating as a result of irrigation pumping; and fluctuating from river stages, which are correlated with 10, 30, and 60 day averages. They show water tables fluctuating in soil with four different rates of permeability. They help to explain why estimated changes in crop responses from ARMPP are beneficial because of raised water tables or because of lower water table peaks. They also explain why there were damaging effects from water table encroachment into the root zone, delayed planting, and lowered water table. Hydrographs are included for 8 of the reaches.

Figure 56 shows the type of study that was made on the various areas along the river. The areas designated as "A" consist of: 1. areas where the pre- and post-project piezometric surface and water table was too deep to have any possible effect on crops and the piezometric data may or may not have been interpolated; 2. areas where the change in the average pre- and post-project piezometric surface was 1-foot or less. The areas designated as "B" had water tables calculated for pre- and post-project conditions but the water table had no effect on crops under either set of conditions. The water table had some effect on crops under either pre- or post-project conditions in the areas indicated as "C". The "D" areas are either easement or purchase by the Corps of Engineers.

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Figures 57 through 60, Pages 176 to 190 is a follow-up of the study shown in Figure 56, Pages 166 to 171. Figures 57 through 60 gives the magnitude of the effect of the ARMPP on the crops studies. The values are percentage point changes between pre-project and post-project water table effects on the crops. Where the water table had no effect on the crop the yield was 100 percent. For example, if the yield were 100 percent under pre-project conditions and 150 percent under post-project conditions, the change would be indicated as an increase of 50 percentage points, but if it were 75 percent yield under post-project conditions, the change would be indicated as -25 percentage points. The areas delineated with the indicated percentage point changes were measured and the acres of potential changes in crop yield are given in Table 29, Pages 127 - 130. Potential crop yield changes means that actual land use or crop distribution was not considered in this table and that the acres and magnitude of effect would be actual only if the entire area indicated were in the particular crop associated with that acreage and magnitude of effect. The acreages indicated for forest include the acreages of all the other crops and the acreages for alfalfa include the other crops except forest.

Table 30, Page 131, gives the total potential crop yield changes because of ARMPP for all the acres that were studied. Table 31, Page 132, shows the actual acres that would be affected assuming the indicated land use. There would be, for example, 57 acres of soybeans that would have -50 percentage points change in yield or 20,945 acres with an increase of 50 percentage points change in yield. Overall, 48,153 acres of soybeans would have a 29.1 percentage point yield increase The total average effect was an increase of 27.7 percentage points on 75,651 acres of land assuming that 10 percent was in small grain followed by soybeans, 7 percent cotton, 71 percent soybeans, 4 percent alfalfa and 8 percent forest.

In 1969 there were approximately 13,482 acres of forest land without flood easements or not purchased by the Corps of Engineers that could be affected by the changed water table resulting from ARMPP. This acreage is about 8 percent of the total possible area that could be affected if all the area were forested.

The net weighted average effect of the raised water table on forest vegetation was a beneficial 19 percent increase in the net annual growth rate, based on the presence of moisture within the root zone for longer periods during normally dry seasons of the year. This would improve the net annual growth from 4.4 percent to 5.2 percent of the growing stock, or roughly 6.0 cubic feet per acre worth $0.12 to $0.88 depending upon species, size of tree, and potential product.

There is a potentially detrimental effect of the project on 36 acres or 0.27 percent of the total affected forested area. Due to the water table being within a foot of the surface for 2 months of the growing season, tree growth could be retarded to 75 percent of expected growth. This is $.18 to $.25 per acre. It is also possible, provided a prolonged cycle

(Text continued on page 191)

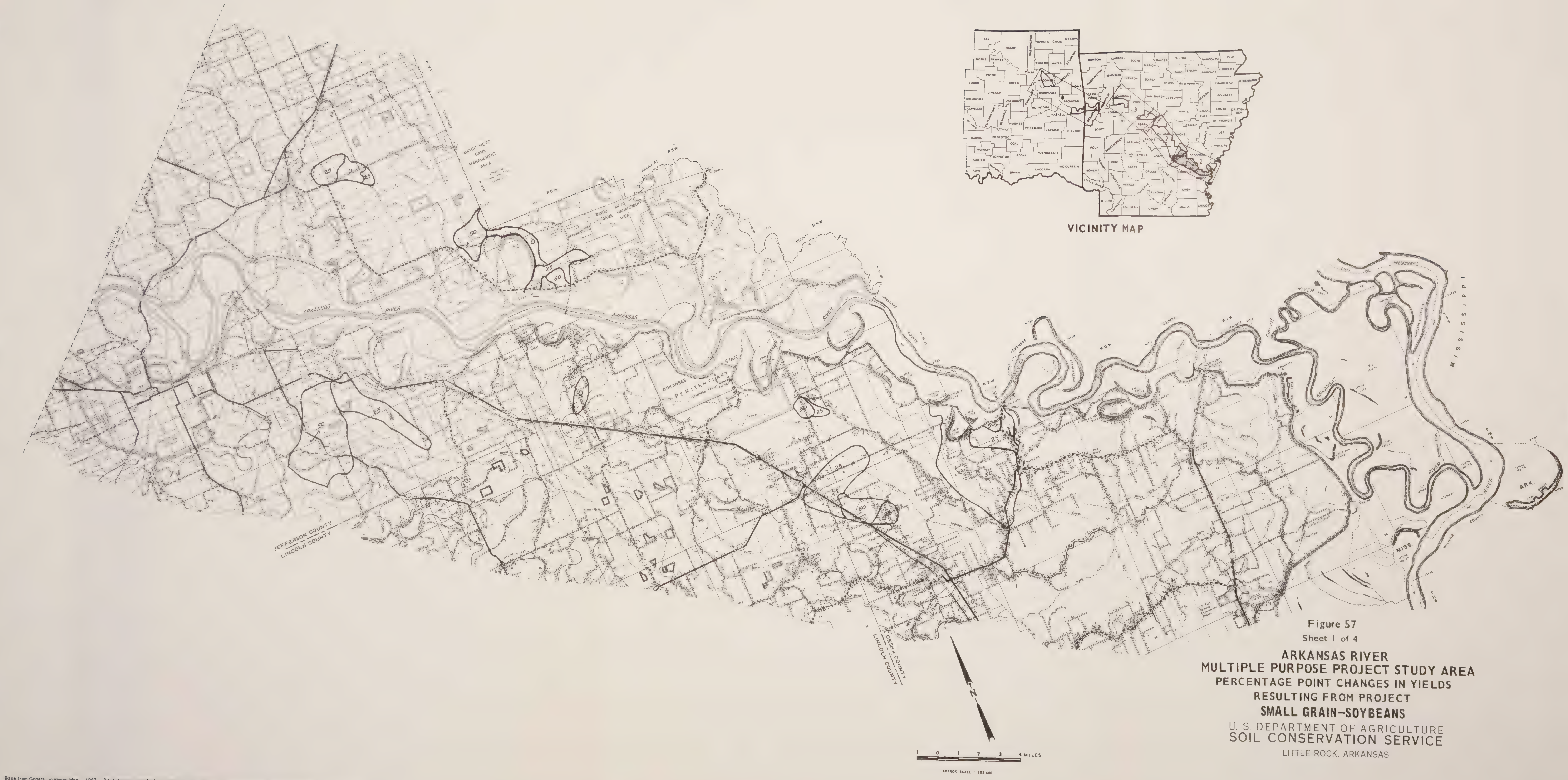

Figure 57

Sheet 1 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
SMALL GRAIN–SOYBEANS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

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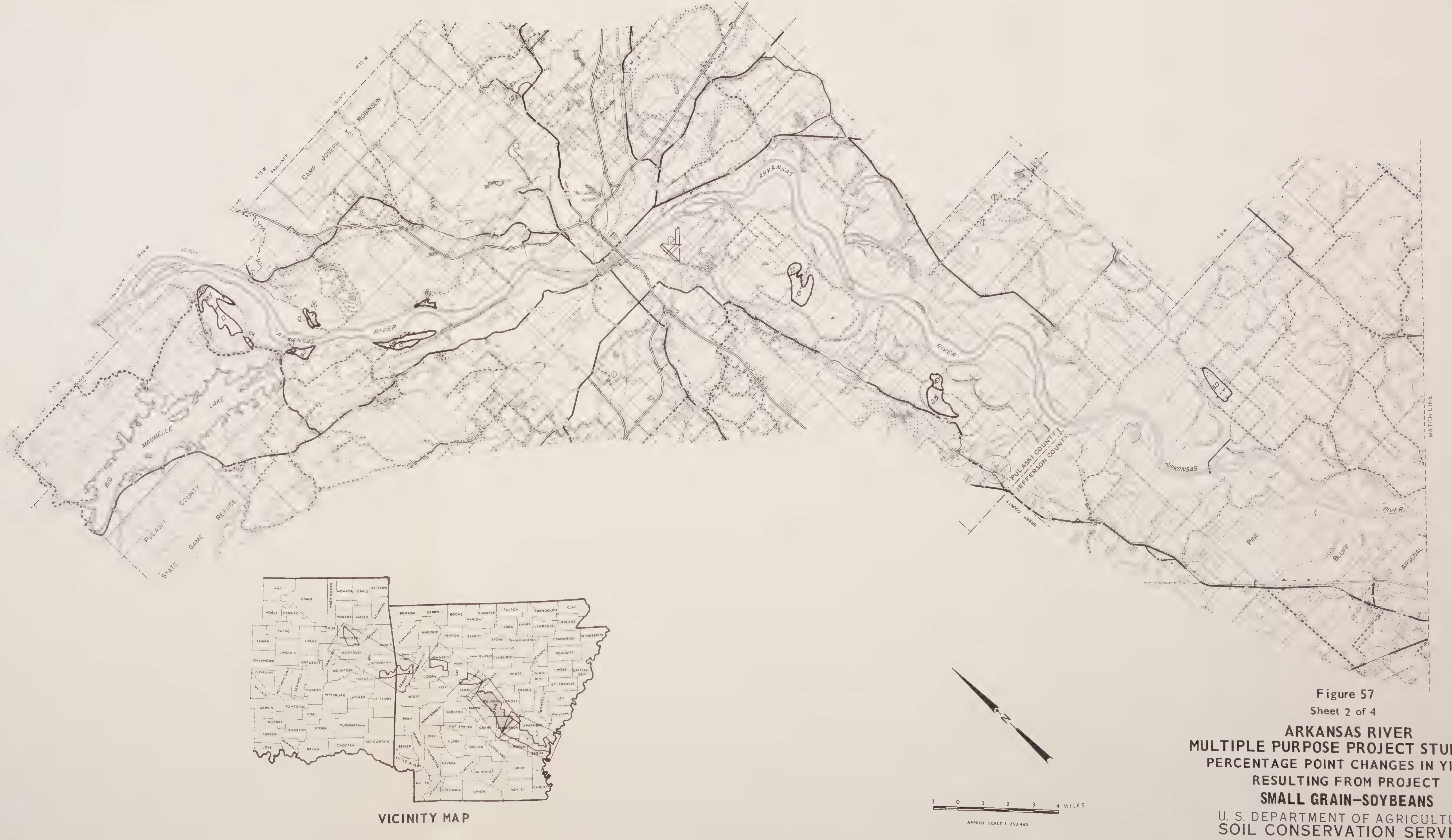

Figure 57

Sheet 2 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
SMALL GRAIN–SOYBEANS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LITTLE ROCK, ARKANSAS

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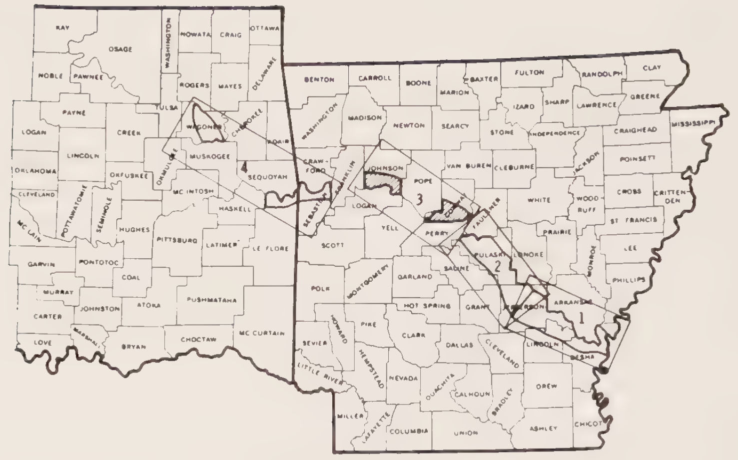
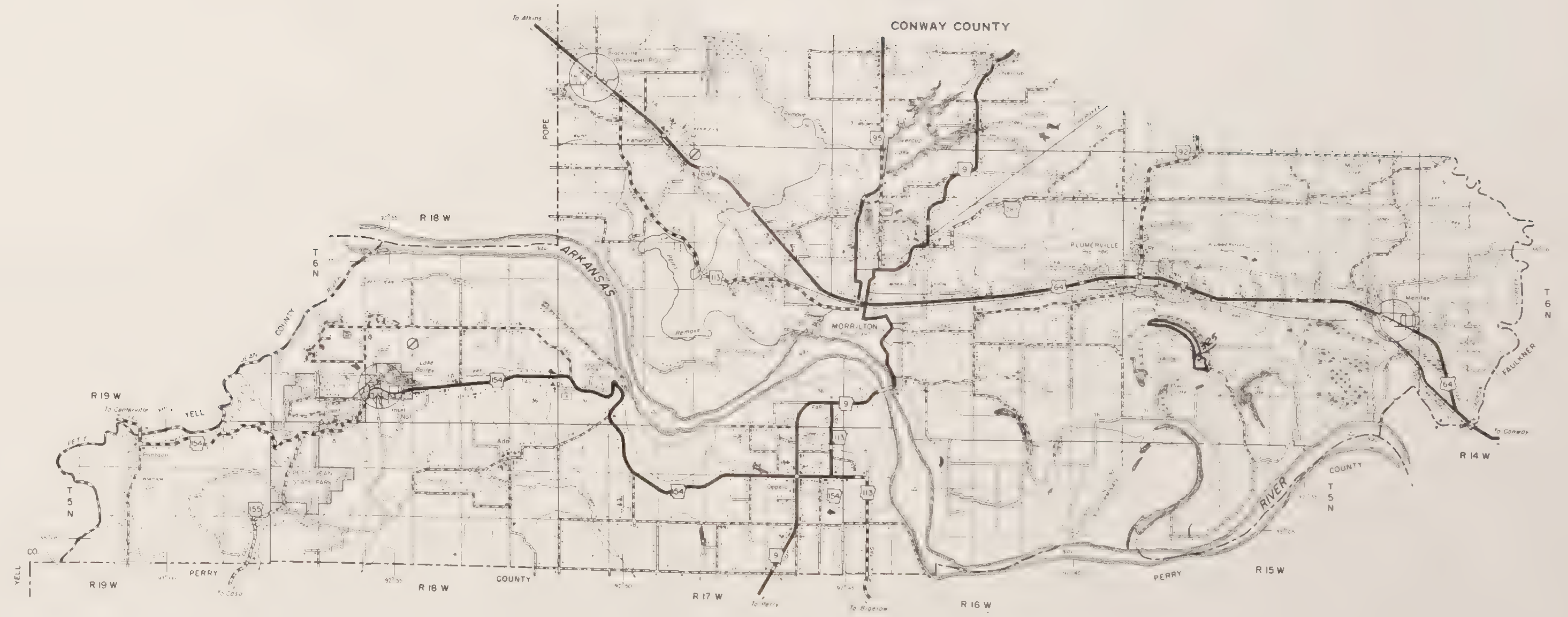


VICINITY MAP



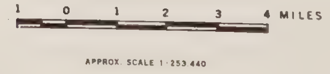


Figure 57

Sheet 3 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
SMALL GRAIN–SOYBEANS

U. S. DEPARTMENT OF AGRICULTURE
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LITTLE ROCK, ARKANSAS

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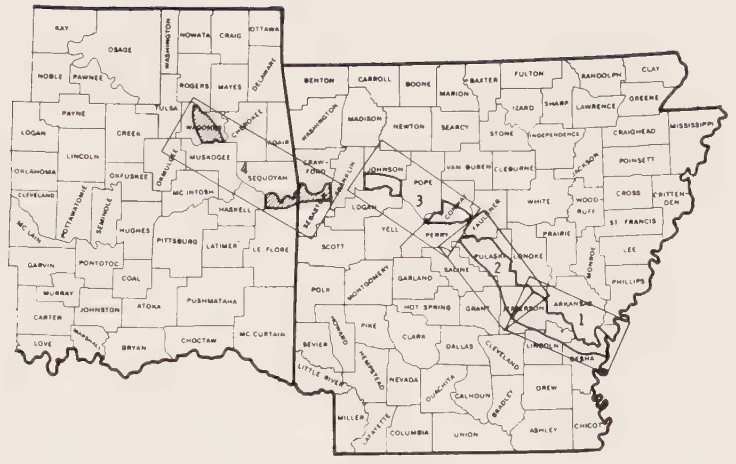

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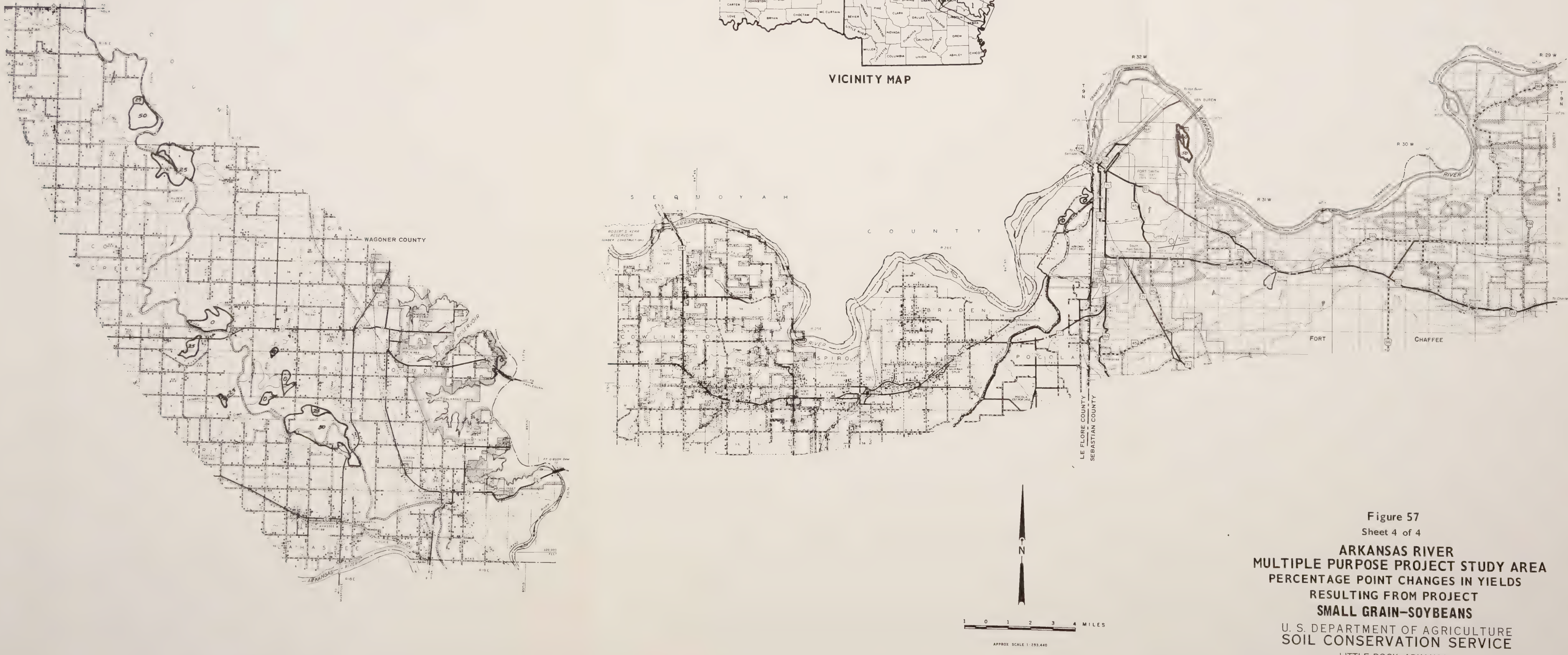

Figure 57

Sheet 4 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
SMALL GRAIN–SOYBEANS

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Figure 58

Sheet 1 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
COTTON OR SOYBEANS

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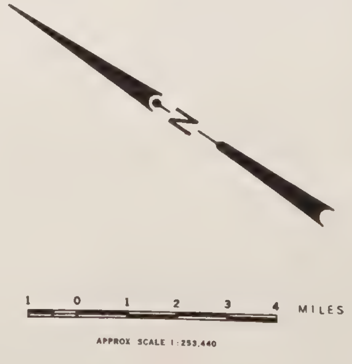

Figure 58
Sheet 2 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
COTTON OR SOYBEANS

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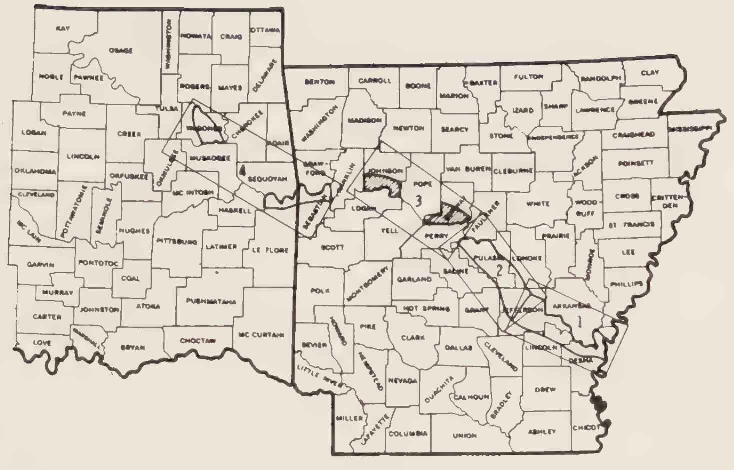

VICINITY MAP

Figure 58

Sheet 3 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
COTTON OR SOYBEANS

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Figure 58
Sheet 4 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
COTTON OR SOYBEANS

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Figure 59

Sheet 1 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
ALFALFA

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Figure 59
Sheet 2 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
ALFALFA

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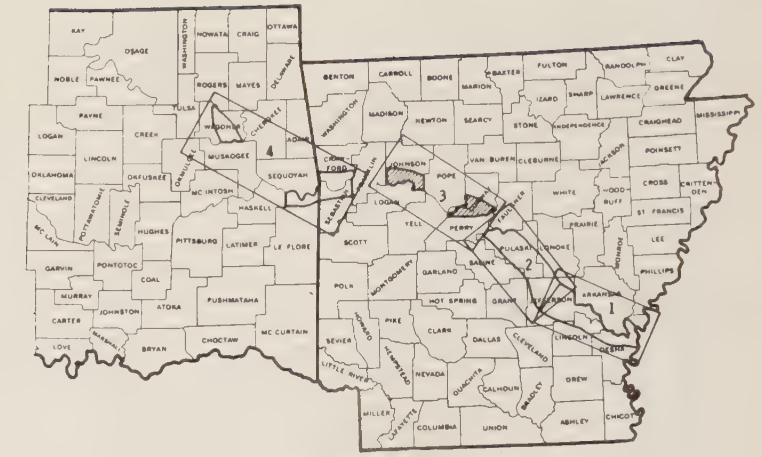

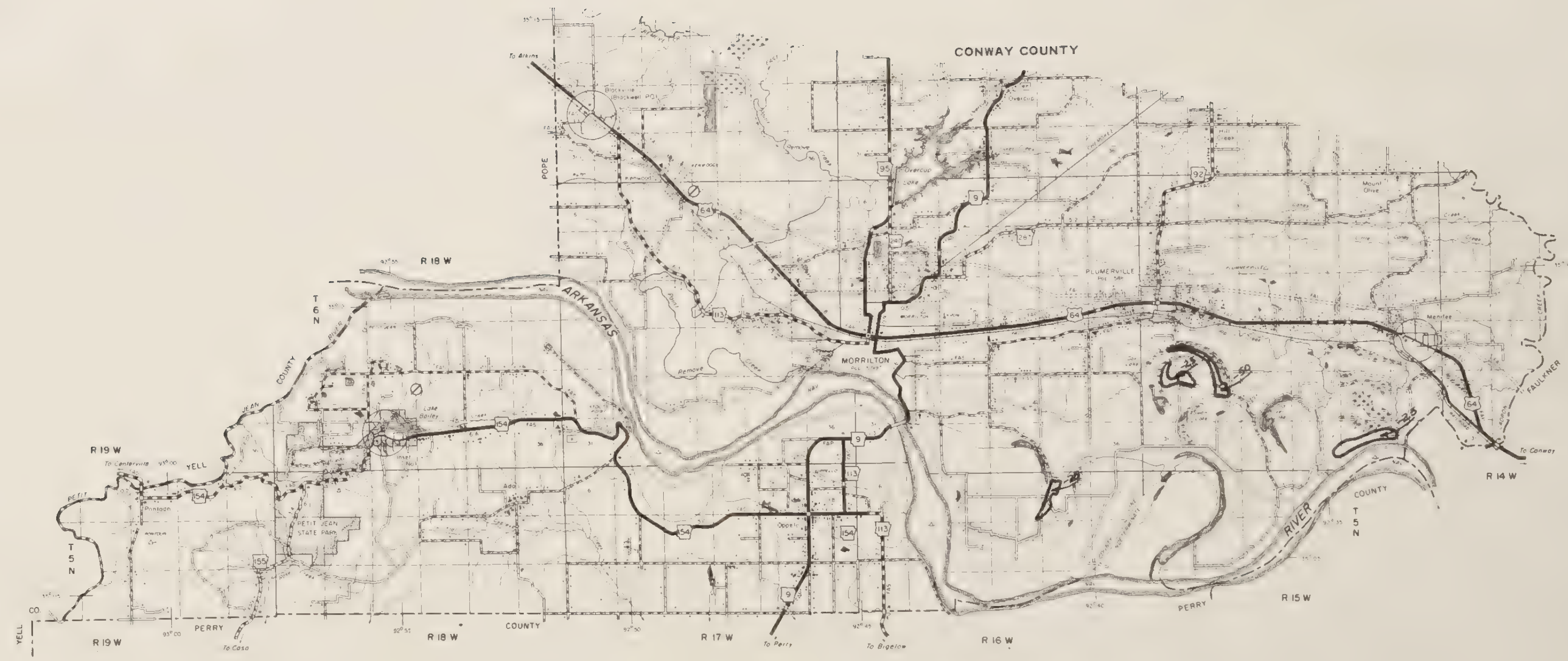

Figure 59

Sheet 3 of 4

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
ALFALFA

U. S. DEPARTMENT OF AGRICULTURE
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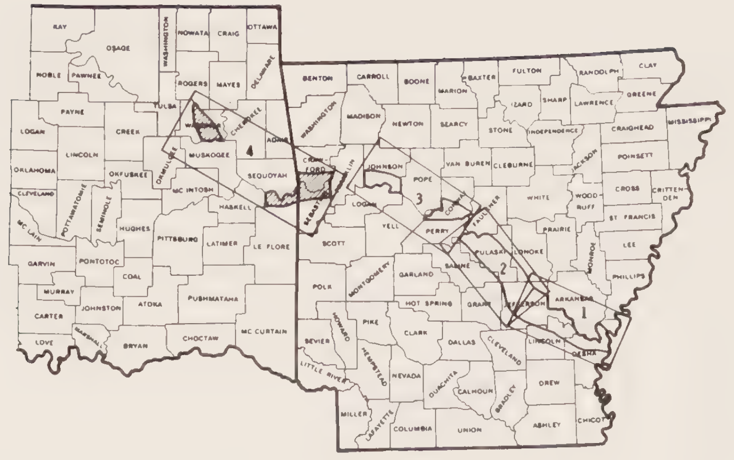

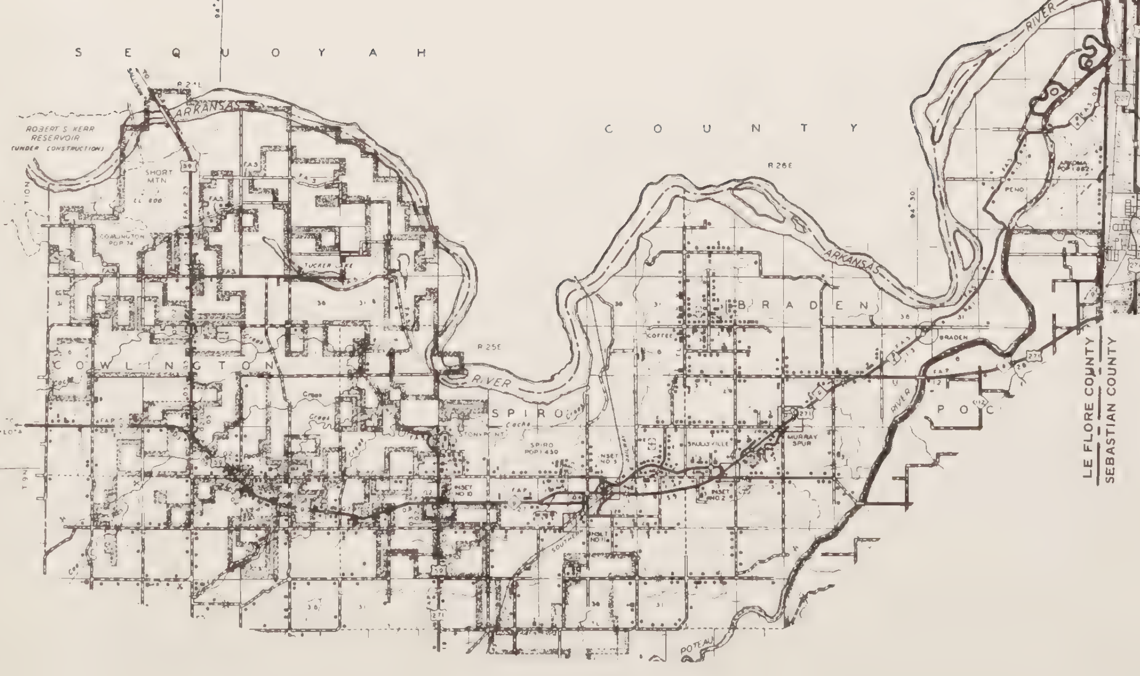

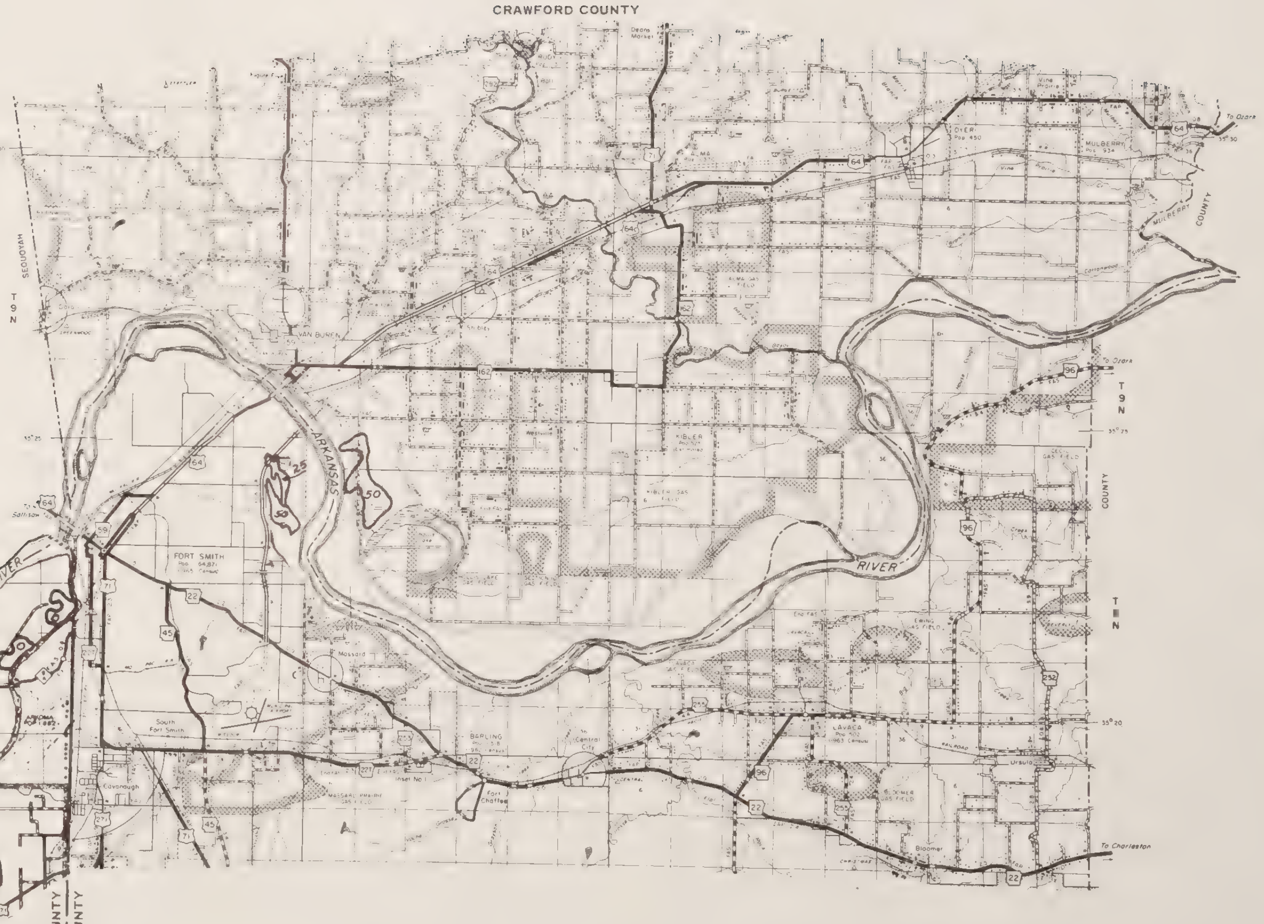

1 0 1 2 3 4 MILES

APPROX SCALE 1:253,440

Figure 59

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ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
ALFALFA

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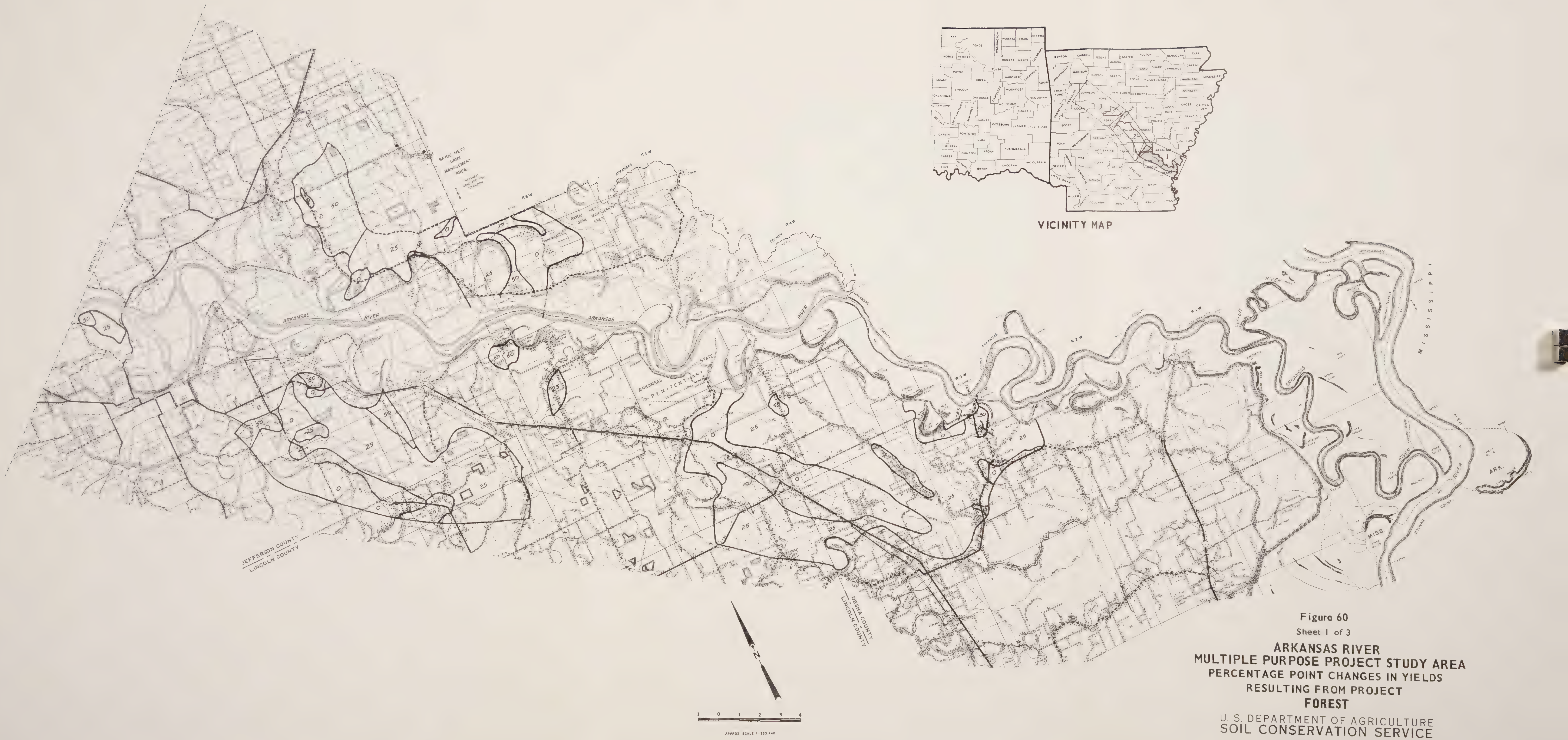

Figure 60
Sheet 1 of 3

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
FOREST

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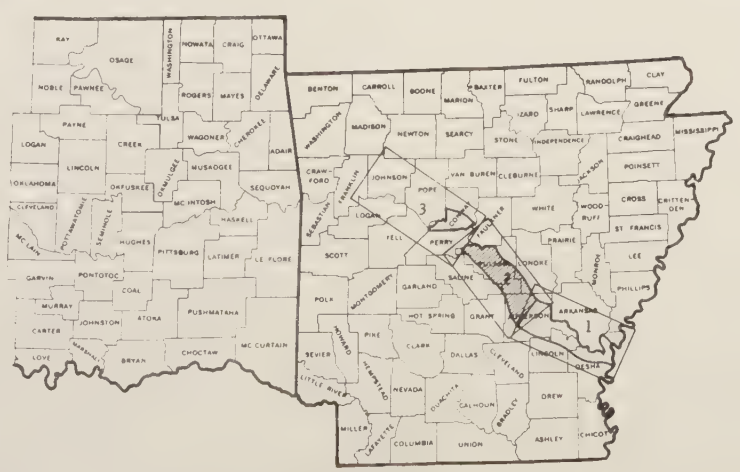

VICINITY MAP

Figure 60

Sheet 2 of 3

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
FOREST

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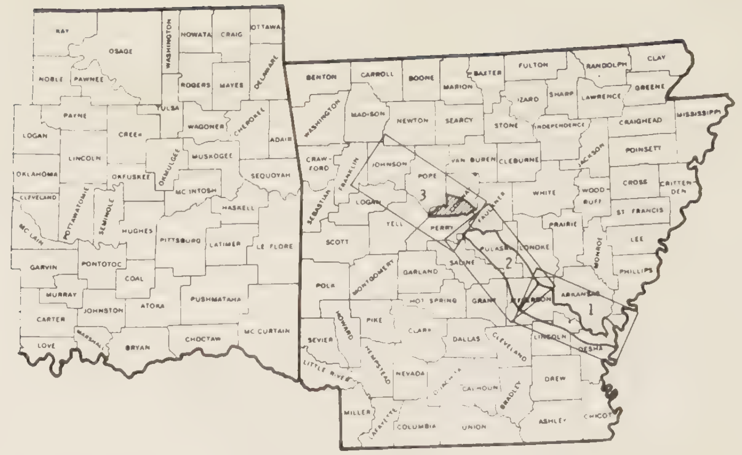

VICINITY MAP

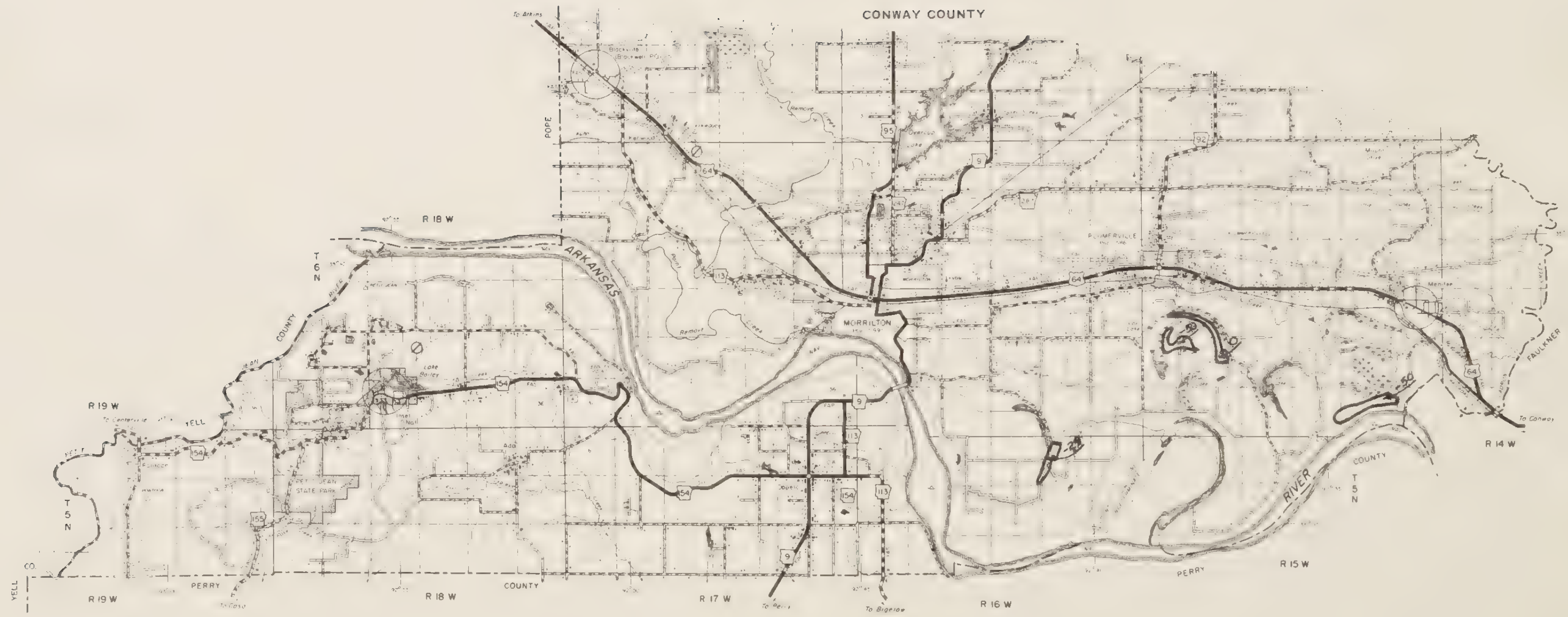

Figure 60
Sheet 3 of 3

ARKANSAS RIVER
MULTIPLE PURPOSE PROJECT STUDY AREA
PERCENTAGE POINT CHANGES IN YIELDS
RESULTING FROM PROJECT
FOREST

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of wet years occurred, that death of trees could result. This is not probable, however, since the wet cycle would have to extend four or more years. It is more likely that species composition would change to more water tolerant species typical of wet land. Generally these more water tolerant species are of a lower economic value under present market conditions. Since the 36 acres now support poor wetland-bottomland forest cover, it is doubtful that a shift in species composition would be potentially economically significant.

The raised water table in the affected area may restrict management opportunities by limiting the harvest season and might make harvesting operations more costly. Probably it will also increase the already limited potential for producing higher value products. This further restriction amounts to approximately $.02 per acre. Therefore, potential net loss per acre varies from $.20 to $.27 per acre on these affected 36 forested acres.

2. Observational Study

The following summaries of conditions that existed on the observational areas from 1963 through 1969 are important to the interpretation of water table effects upon crop responses. It would be illogical to summarize the results obtained without reference to the specific conditions of each year that contributed to the results.

The lowest precipitation of record at Little Rock occurred in 1963 (28 inches where normal is 48 inches). All crops were deficient in moisture and no water tables were observed.

Precipitation was near normal in 1964 but the distribution was poor for crop production. There was practically no usable rainfall for two months following planting in May and generally no crop or poor stands resulted. River stages were low.

The first year of post-project conditions existed on Hartman and McLean Bottoms in 1965 and pool stage was near static most of the year. Rainfall was below normal in June, July, and August and soil moisture was deficient for most crops.

Stabilized water table and piezometeric conditions were present in 1966 on Hartman and McLean Bottoms. Total rainfall was near normal on Fourche Island and 12 inches below normal on McLean Bottoms. No rainfall occurred on Fourche Island in June and there was no significant rainfall between the 20th of May and the 20th of July; however, 15 inches fell in August. Crop losses from low rainfall and beneficial use of water from the water table were apparent and significant. Critical maximum depths of water table which were of benefit to crops were readily ascertainable. High river and pool stages occurred in February and April.

River stages were high at Little Rock in July but pool stages were normal throughout 1967 near Hartman and McLean Bottoms. Precipitation was near normal and there was no significant moisture stress in the crops. Benefits from the water table were obscure; but, no damages were observed.

Exceptionally high river and pool stages were present during the first half of 1968 but were near normal during the second half. Rainfall was up to 17 inches above normal. Planting was delayed because of heavy rainfall in May, shallow water tables, perched water tables, and surface ponding. No moisture stress was observed in the crops. Dam No. 6 near Fourche Island was closed in September.

In 1969, pool stages were similar to those in 1968 (exceptionally high during the first six months and normal during the last six months). Total precipitation was near normal but 2/3 of the months had below normal rainfall. Damages from shallow water table resulted in areas not being planted or in delayed planting. Where water tables were below the root zones, considerable moisture stress existed in the plants. The first full year of post-project conditions were observed on Fourche Island in 1969. Both water tables and piezometric surfaces were generally lower than in the preceding year before closure.

There follows a brief discussion of the observational studies, by years, from the first, 1963, through 1969.

a. 1963

The total area included in the observational study of the agricultural aspects of the ARMPP during the 1963 crop year was 27,629 acres. The use of this land was: crops, 86.6 percent; pasture, 1.0 percent; forest, 10.0 percent, idle, 1.5 percent; and other, 0.8 percent. Twelve percent of the land was double cropped; wheat and soybeans were the principal crops involved.

Forest cover in the observational study areas is scattered and in small blocks, usually subject to overflow or too wet for agricultural use. Most of the forest areas have a history of overcutting and high grading. There is little attempt at management. Unless the ARMPP has adverse effects on drainage systems in the study areas, eventually most of the forest cover will be cleared for agriculture.

There was a wide range in yield of the major crops between soils and management operations within each area. Estimated over-average yields for the aggregate of all study areas during 1963 were: cotton, 651 lbs. lint; soybeans, 25.4 bu.; wheat, 36.6 bu.; corn, 43.7 bu.; alfalfa, 3.97 tons; and other hay, 1.73 tons. These yields are all somewhat higher than those estimated for Arkansas by the Statistical Reporting Service.

Most reporting farmers considered 1963 cotton yields average to above average, although soybean yields were felt to be below average. Dry weather was the chief reason given for lower-than-average soybean yields. Insect damage to soybeans was reported to be more serious than for cotton. However, the damage to either was not great.

Farming in the surveyed areas was conducted primarily by full-time farmers who rent more than two-thirds of the land they operate. The average size operation for all areas in terms of crops and pasture acres was approximately 510 acres. Most farm operations were accomplished with three to four-

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plow tractors and associated farm equipment. Most cultural and management practices were classed as average or better.

The observational study in 1963 yielded limited data for correlations of the fluctuations of water table and crop response because of low rainfall and low river stages during the growing season. The piezometric surface gradually lowered in all areas during the growing season and continued to do so into the next year.

Had it been a year with more normal rainfall and river stages, about 1/3 of the observation points would probably have provided data for correlating water table or excess surface moisture with plant response. The observational study did give data showing pre-project conditions in the three areas with extremely low rainfall and river stages; a situation which will probably never exist again.

It was impossible to determine the results of a fluctuating water table on crop response in 1963 on the three areas because the piezometric surface and water table gradually lowered during the growing season and no water tables were present in the root zones of crops, except possibly alfalfa. The study gave valuable information on crop response during a drought year, the lowest precipitation ever recorded. Visual estimates of crop yields at the observation points do not always correlate well with field yields because either the observation points does not represent the average condition of the entire field, operator estimates of yields or area are in error, or visual estimates are not reliable.

b. 1964

The low rainfall and low river stages during the growing season caused conditions from which only limited data were obtained for correlating the fluctuation of water tables and plant response. Nearly all of the piezometric surfaces either gradually lowered or remained steady during the growing season. Even though the total precipitation was about normal for the year, most of it occurred before May and after August. A higher water table during July and August 1964 would have been beneficial in most cases. However, lack of moisture in the top 4 inches of soil caused more crop loss through poor germination than through lack of soil moisture for the growing plants.

Correlations between soil moisture content and soil moisture tension were close.

The large change in land use on the observational areas was caused mainly by two factors: (1) unfavorable distribution of rainfall, and (2) change of policy on acreage allotment of wheat.

Most crop yields were probably depressed by the unfavorable weather. Cotton in McLean and Hartman Bottoms suffered most. Soybeans appeared to be most affected in Fourche Island.

Production costs were affected, as were crop yields, by the unfavorable distribution of rainfall during the cropping season. In several instances, fields were seeded to soybeans as many as three times without an adequate

stand being established. Before each planting a new seedbed was prepared. Production costs were thus increased by preparation and seeding costs plus the cost of additional seed for seed for each reseeding. During 1964, there was too little moisture during the critical land preparation and seeding period. Too much rainfall could have a comparable effect of increasing costs.

In cotton production it was noted that reaction of the operators to the prospects of a low yield caused them to reduce their spray program for insect control and defoliation, thus reducing production costs. Harvesting costs would also be reduced with reduced yields. Yields may have been further depressed by the operators' reluctance to apply practices that would have been applied had the prospect for a higher yield been better. By curtailing further spending when yield prospects appeared low, they were attempting to minimize additional loss.

There was little change from 1963 in the number of acres operated as a unit with average cropland acreage ranging from 255 acres for McLean Bottoms operators to 620 for Fourche Island operators. Average acreage of pasture ranged from 38 for Fourche Island operators to 120 for McLean Bottoms operators. Seventy to 80 percent of the cropland is leased or rented. An average of 9, 43, and 53 percent of the pasture is rented or leased for Fourche Island, McLean Bottoms, and Hartman Bottoms operators, respectively. Fifty to 80 percent of the farm units include a livestock enterprise.

The effect of a fluctuating water table on crop response was not determinable from the 1964 data obtained because the water table did not fluctuate in the root zone of the crops at the observation points during the growing season. However, the data collected for 1964 had value by showing the cropping pattern and yields for different locations throughout the bottom areas under the conditions that existed, and with the management practices applied.

Soybean yields were influenced mostly by lack of rainfall following planting.

Cotton yields were influenced mostly by lack of rainfall during the time when bolls were developing and maturing and by high rainfall when the bolls were opening and at harvest time.

Supplemental irrigation was practiced during 1964 by four operators on relatively few acres. Crops irrigated included cotton, soybeans, corn, alfalfa, and commercial vegetables. Although irrigation appears to be increasing, the incidence of the practice, to date, is not considered of such significance to justify a detailed intensive study.

The soil moisture content and soil moisture tension correlation study gave valuable information for future use in the observational study and in verifying the reliability of soil moisture tensiometers as a tool for studying soil moisture-plant growth relationships.

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c. 1965

Planting and germination conditions were favorable in 1965. However, most of the observation points were deficient in soil moisture during parts of the growing season. Fourche Island, the west part of McLean Bottoms, and all of Upper Hartman Bottoms were particularly dry in August. Total average annual precipitation was 11.45 inches below normal on Fourche Island; 4.48 inches below normal on Hartman Bottoms; and 6.23 inches below normal on McLean Bottoms.

Water tables were observed at 24 of the observation points at depths of from 1/2 foot to 10 feet below the surface. No damaging effects on the crops could be attributed to the water table at any of the observation points. However, the crops at 10 of the observation points may have benefited by the use of water from the water table. Damaging effects occurred at three observation points because of excess ponded surface water.

The difference between piezometric pressure and the water table was as much as 2 1/2 feet.

It appears that most of the effect of the Dardanelle Reservoir on the piezometric surfaces on Hartman and McLean Bottoms had occurred by the middle of 1965. The amount of rise of the piezometric surfaces apparently depended more upon its elevation at the time of closure of Dardanelle Dam than upon its distance from the reservoir. Some of the piezometric pressures in the deep USGS piezometers did not correlate well with the shallow piezometers at the observation points. The pumping from Six Mile Creek by the Corps of Engineers appears to be quite effective in keeping piezometric surfaces below the ground surface and pool elevation for considerable distances from the pumping plant and Six Mile Creek.

The crops at six of the observation points were irrigated and irrigation equipment was available at five other points.

The rain gage system on Fourche Island was modified to give better rainfall information at the observation points, but not as much rainfall data for the entire area. The rainfall data on Hartman and McLean Bottoms was essential to evaluate the crop response from the conditions which existed on these areas.

The major land use changes were a decrease in the number of acres of wheat and an increase in the number of acres of soybeans.

Average crop yields were more nearly normal in 1965 than in 1964. Cotton yields were considerably better in Hartman and McLean Bottoms where yields in 1964 were extremely low. For the three areas, cotton yields averaged 40 percent higher in 1965 than in 1964. All the increase was in Hartman and McLean Bottoms. Yields in 1965 were slightly lower in the Fourche Island area. The weather made the difference. There was no appreciable difference in fertilization or other practices affecting yields.

Soybean yields were slightly higher in all areas. The greatest difference was in late soybeans following small grain. The growing season was more favorable for late soybeans.

Small grain yields were slightly lower in 1965 than in 1964. Heavy early rains were believed to be the cause of lower yields in wheat. Fertilization practices were about the same as in 1964.

The only reported damage to crops by surface water or high water table apparently associated with the ARMPP was in Lower Hartman Bottoms. Some wheat drowned out from ponding in an area that was at and below pool level elevation. Soybean yields following small grain were good in this general area.

Production costs were near normal during 1965. There were few instances where crops had to be planted a second time before adequate stands were established. Operations required for seedbed preparation were no greater than normal. Weed control problems were considered normal during 1965. Insects were controlled on cotton with the number of sprays that appear to be normal for the areas.

It was a particularly favorable year for completing harvest in the fall. A greater percentage of cotton was machine harvested in 1965 than in previous years. More effective use of machinery was possible because of favorable weather conditions.

There was an increase in crop acreage of 38 to 50 acres per operation between 1964 and 1965. Crop acreage in Fourche Island has increased each year since 1963. Acreage in Hartman and McLean decreased in 1964, but increased in 1965 almost back to the 1963 level. Lower acreage in 1964 was caused mainly by land idled when crop stands could not be established. Land purchased for levees has reduced the acreage available in Hartman and McLean to some extent. Crop acreages ranged from 300 acres per operator for the McLean Bottoms operators to 677 acres average for the Fourche Island farmers.

Proportions of land owned or rented in the operations did not change significantly between 1964 and 1965. For the most part, the land was operated by the same farmers in 1965 who operated it in 1964.

Fifty to 82 percent of the operators had livestock in their operations during 1965 compared to 50 to 80 percent in 1964. The size of the livestock enterprises were also about the same as in 1964.

The data obtained where water tables were present within the root zones and ponded surface water occurred gave valuable information as to the effect of these on crop response. One important condition that was not observed was the presence of a shallow water table with normal or about normal rainfall during the active stages of plant growth. This would be the most critical situation. The water tables that were observed in the root zones of the crops were not detrimental, but rather appeared to be beneficial. However, this does not imply that under a different set of conditions of weather, crops, varieties, and management the effects would or would not have appeared to be beneficial. Damage to crops was observed in some cases where surface water ponding existed.

Single shallow piezometers were not sufficient in some cases to give the needed information on water table. Differences of 2-1/2 feet or more existed between water table and piezometric surface.

Below normal rainfall in July and August was damaging to crop growth and production at most of the observation points. Supplemental irrigation or higher water tables would have been beneficial to the crops in most of these cases. However, this study was not designed to determine the feasibility of or the returns from irrigation and no conclusions were drawn from the data collected concerning the economic feasibility of irrigation.

The crops were irrigated at 6 of the observation points in 1965 and there were irrigation systems which could have been used at 5 others. The operators who irrigated reported some yields of 2 bales of cotton and 37 bushels of soybeans per acre. Unirrigated check plots were not left and irrigation costs were not kept. Consequently, the benefits of the irrigation could not be readily determined.

The land use inventory showed some significant land use changes but these were not associated with the changes in subsurface water conditions.

These land use changes or differences compared to previous years of observation appeared to be more nearly associated with a lack of adequate moisture during 1964. There may also be some adjustment to governmental program affecting wheat acreage. The trend toward more soybeans and alfalfa appeared positive.

Excellent harvest conditions made it possible for rapid, early harvest, land preparation, and planting of the small grain.

d. 1966

Some especially valuable information was obtained in 1966. The critical maximum depth of the water table to be of benefit to cotton and soybean production was obtained. Also, the data showed the critical minimum depth of the water table under sorghum. Alfalfa was benefited by a water table ranging shallower than 3 feet to deeper than 12 feet. Water tables about 3 feet deep were not damaging to soybeans and damage of soybeans by water table more shallow than 3 feet was not observed.

There were six different kinds of crops at the observation points. More than half of the observation points were cotton or soybeans fields. The crops at three of the observation points were irrigated.

On Fourche Island there was no rainfall in June, which caused failure of some soybean crops due to poor germination. Where stands were obtained, there was not a large moisture deficiency for the rest of the growing season.

There was considerable moisture stress in the plants on Hartman Bottoms at each observation during the summer except the weeks of August 22 and September 5.

The average soil moisture tensions were higher under soybeans than under cotton.

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The piezometric surfaces in the deep and shallow piezometers on Fourche Island were about the same elevation and all were generally higher than the Arkansas River stage at Little Rock. The piezometric surfaces and water table raised in August because of heavy rainfall.

Practically all of the piezometric surfaces on Hartman and McLean Bottoms were between elevation 336 and 340 ft. msl, and the fluctuations were from one to two feet. Precipitation had very little effect on the fluctuation of the piezometric surface. The pumping from Six Mile Creek was quite effective in keeping piezometric surfaces below the ground surface and pool elevation for considerable distances from the pumping plant and Six Mile Creek. The Arkansas River stage at R.M. 297.4 was between 337 and 338 ft. msl most of the year.

Water table was observed at 34 of the observation points. At 18 of these the water table had no effect on the crops; at 15 the crops were benefited by the water table; and at one there were detrimental effects.

Trends in land use changes from 1963 to present have not involved large acreages and apparently none has been a result of ARMPP. There have been large acreage changes in land use from year to year but no trends involving large acreages during the 4 years. About 500 acres of forest have been cleared since 1963. Alfalfa acreage has increased each year and there were about 500 acres more in 1966 than 1963; most of this increase was on McLean Bottoms.

Cotton apparently benefited from a 5 1/2 foot water table. Alfalfa benefited from water tables as deep as 12 feet. Water tables at 2 to 4 feet deep benefited soybeans. Water tables deeper than 5.5 feet had no effect on cotton and soybeans.

The supplemental study to delineate and evaluate marked effects on crops apparently due to water table in lower Hartman Bottoms showed that the critical maximum depth for benefits to cotton and soybeans on sand soil was 5 1/2 feet and on fine textured soil 6 1/2 feet for these two crops. It also showed that the benefit to these crops under conditions present in 1966 was considerable.

On the 5th of May following heavy rainfall, a 1 1/2 foot water table had no apparent damage on oats in the heading stage of growth.

The critical minimum depth of the water table under sorghum was 2.3 feet. Shallower than this caused damage; deeper than this there was no damage.

Soybeans were benefited considerably by a steady 3.3 foot or fluctuating 2.4 to 2.7 foot water table.

Alfalfa was not damaged by a 2.9 foot water table; however, large benefits were not apparent.

The economic aspects of the observation study were discontinued due to limited funds.

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Based on data gathered, no trends in such items as change in land use, change in general levels of management or production, or changes in crops or varieties were apparent. However, data gathered in 1966 confirms information in previous report of the continuing beneficial effects to major crops' growth and development in limited areas from elevated and generally steady water tables and insignificant adverse effects as a result of ARMPP. However, this should not be construed as being a projection of expected effects in a crop year of above normal rainfall. Areas appearing to be benefited now, could be adversely affected by a change in the physical or chemical condition of the soil (especially an increase in salinity) over a period of years. This could be the dominating factor of crop production rather than water table *per se*. However, the accumulation of salts in the soil due to the ARMPP was not studied nor evaluated because the rainfall amounts and distribution in the study area make this improbable; but plans for investigating this are being considered.

Under conditions existing in August in Fourche Island on all observation points and USGS piezometers, heavy rainfall (14.63 inches) significantly increased water table elevations at depths ranging from 3.8 feet (SCS and USGS piezometers) to about 25 feet (USGS piezometers.)

Under conditions existing in February in Hartman and McLean Bottoms, a rainfall of 5 to 6 inches increased piezometric surfaces very little (0.3 foot.)

Under conditions existing in August in Hartman Bottoms, moderately heavy rainfall (4.5 inches) raised water table elevations approximately one foot at a water table depth of about 3 1/2 feet. A similar increase in water did not occur in McLean Bottoms in August due possibly to removal of rainfall by pumping from Six Mile Creek.

Under conditions prevailing in 1965 and 1966, the pumping installation on Six Mile Creek will effectively keep piezometric surfaces below the ground surface and pool elevation for considerable distances from pumping plant and Six Mile Creek.

e. 1967

The determination of beneficial effects to crops from the water table in 1967 was difficult because of the near sufficiency of soil moisture from rainfall. Some valuable information about plant growth and yield was obtained on soybeans with water tables less than one foot deep.

There were seven kinds of crops observed in 1967. About one half of the observation points were in soybeans and one fourth were in cotton. There was supplemental irrigation at two or three observation points.

The total rainfall for 1967 was about normal. Soil moisture was sufficient for normal plant growth during most of the year. Early April and September were the driest periods. Moisture stress in the plants was not significant.

Soil moisture tension at the 3 foot depth was higher under soybeans than under cotton. More than half of the soil moisture tension observations were in the range of field capacity soil moisture content (less than 20 centibars of tension).

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On Fourche Island the piezometric surface and water table fluctuated similarly in both time and magnitude and were generally higher in elevation than the Arkansas River Stage at Little Rock. However, there appeared to be no correlation with river stage.

On Hartman and McLean Bottoms the piezometric surface and water table fluctuated between elevation 336 and 340 ft. msl except at two locations and those that were affected by pumping from Six Mile Creek. The Arkansas River Stage at R.M. 297.4 also fluctuated between these elevations except for three weeks in July when it reached about 343 ft. msl. No water tables were observed in the USDA piezometers on the Upper Hartman Bottoms nor on the west part of McLean Bottoms.

Water tables were observed at 32 observation points. No damages could be definitely attributed to high water tables. Benefits that may have occurred from the water tables were obscure at some locations because of sufficient soil moisture and rainfall. The total acres of soybeans, small grain, cotton, and alfalfa for 1963 through 1967 was more than three-fourths of the total land use. With 1967, an analysis of five years of land use record had been completed. It appeared doubtful that the objective of the land use inventory could be reached. Economic and weather factors have much more effect on land use changes than the change in the depth to water table as a result of the ARMPP.

Some low flow measurements and photographs were made in the ditches constructed under authority of PL-566 on Fourche Island to obtain additional pre-project information on the ditch flows and bank stability for comparison with post-project conditions.

At two locations a 4 to 6-1/2 foot water table apparently benefited cotton but a 6 foot water table was not beneficial at another location. Alfalfa undoubtedly benefited from a water table shallower than 6 feet. A 2 to 3-1/2 foot water table was apparently not damaging to soybeans. A 6.8 to 8.7 foot water table may have contributed to a luxuriant growth of cotton. Severe lodging of the soybeans may have been caused by a 1.8 to 3.4 foot water table. At one observation point and the observations north and south of it, the water table averaged 0.6 and 5.5 feet deep but there was no visible difference in production; however, where the water table was less than 1/2 foot deep the early growth of the soybean plants was abnormally affected. Where the water table was 2 feet or closer to the surface, mature soybean tap roots were short and stubby and the feeder roots were long and horizontal. A water table between 4 and 5.3 feet deep provided some water to soybeans. Surface flooding and ponding at least four times compounded with a high water table may have caused some reduction of yield. A 2 to 3 foot water table was not detrimental to alfalfa production; however, it had a marked effect on root development and distribution in the soil.

Beneficial effects can be derived from water tables as deep as 5 feet or more during periods of low rainfall when the crop is growing even though the annual rainfall is near normal. Frequent surface ponding of rainfall with a water table 2 to 3 feet deep will not reduce soybean production significantly. Soybean production will not be materially affected by a water table fluctuating between 0.3 to 1.2 feet deep; however, early plant

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growth and root systems will be affected noticeably. Under conditions existing near one observation point, evapotranspiration had no effect on the elevation of the water table that averaged from 2/3 to 5 1/2 feet deep over a lateral distance of 120 feet.

Rainfall in April, May, and September raised the water table and piezometric surface on Fourche Island, but a high Arkansas River stage (235 ft. msl at Little Rock) in July had no significant effect on them.

The piezometric surfaces and water tables on Hartman Bottoms and McLean Bottoms are not significantly affected by rainfall, but there is a slight trend toward correlation with pool stage.

Under conditions prevailing from 1965 through 1967, the pumping installation on Six Mile Creek will effectively keep the piezometric surface and water table below the pool elevation for considerable distances from the pumping plant and Six Mile Creek.

f. 1968

In 1968 the rainfall and river and pool stages were considerably higher than had occurred in any previous year of this study. This resulted in conditions of water table and piezometric surface which had not previously been observed.

The total rainfall for 1968 on the observational areas ranged from 48.77 to 59.56 inches.

At one spot 13.37 inches were measured in May. The average total rainfall was 8.54, 14.03, and 7.87 inches above normal for Fourche Island, Hartman Bottoms, and McLean Bottoms respectively. High rainfall and water tables delayed planting at several observation points.

Soil moisture was sufficient most of the year for normal plant growth. August and September were the driest from the plant growth standpoint, but no significant moisture stress was observed in the plants.

The soil moisture tension at the 3-foot depth was 15 centibars higher under soybeans than under cotton. About 60 percent of the observations showed soil moisture tensions in the range of field capacity soil moisture content.

Where the piezometric surface was higher than elevation 233 on Fourche Island, it was not affected by high river stages during the first part of 1968. Where it was below this elevation, it raised significantly. The high rainfall amounts in May caused the piezometric surface to raise regardless of elevation. The piezometric surface at only one observed piezometer raised during the first two months after closure of Dam No. 6.

On Lower Hartman Bottoms the piezometric surface raised 2 1/2 to 5 feet in the first half of 1968 because of high pool stage and large amounts of rainfall. By September it was about normal. The elevation of the piezometric surface averaged about 340. The water table peaks at three observation points resulted from hill water or Hartman Lake and not pool stage.

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At eight observation points the water table was below pool stage elevation by as much as two feet during August and September.

There was some small grain and alfalfa damage in the lower part of McLean Bottoms in the spring because of high water tables and surface flooding. These also caused some crop yield reduction because of planting delays. The pool stage was generally higher than the piezometric surface during the first half of 1968 and lower during the last half. The piezometric surface fluctuated from 2.5 to 4.2 feet at any given location. This large fluctuation was caused by high pool stages of long duration.

There were 41 observation points where water tables were observed. At 20 of these the water table had no effect on the crop. There were apparent benefits from the water table at 14 observation points. At six observation points there was damage to crop production from delayed planting caused by water table. Wheat was damaged by a rising water table at one observation point, but was neither damaged nor benefited at another point.

Surface water ponding caused damage to eight of the nine observation points where it occurred. Perched water tables were observed at four observation points, three of which were on Fourche Island.

In general, the damage by shallow water tables in 1968 was caused by a considerable delay in planting date and not the effect of the water table *per se* on the growing crops.

High river stages as in 1969 will not affect the piezometric surface on Fourche Island where it is above elevation 233, but large amounts of rainfall will affect it regardless of elevation. Closure of Dam No. 6 had no immediate (first two months) obvious effect on the piezometric surface above elevation 230.

On Lower Hartman Bottoms the water table fluctuated from 2 feet below static pool elevation because of evapotranspiration to $3\frac{1}{2}$ feet above because of high pool stages (elevation 336 to $341\frac{1}{2}$).

The high pool stages and ponded surface water both caused crop damages to alfalfa and small grain in the eastern part of McLean Bottoms. The shallow water table caused a delay of planting dates of soybeans in the low areas which resulted in lower production.

The pumping installation on Six Mile Creek did not maintain the water table and surface water in that vicinity at as low elevations as it had in previous years.

The conditions of rainfall and pool stages that existed in 1968 do not have an expected high frequency of occurrence.

Crop benefits can be expected from water tables as deep as five feet or more during periods of rainfall deficiency. Crop damages by shallow water tables generally occurred because of a delay in planting rather than actual water table damage to the plants.

g. 1969

Soil moisture was insufficient for normal crop growth at about half of the observation points. This resulted from 3 to 4 inches of rainfall deficiency in the higher growth rate periods of July, August, and September where the water table was not within reach of the roots. The soil moisture tension at the 3-foot depth averaged about 10 centibars higher in 1969 than in previous years.

At most of the locations on Fourche Island where the piezometric surface

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was observed, it was generally lower in 1969 than in 1968. After June it was about two feet lower. The only place where the observed piezometric surface was higher was at piezometer T1N-R11W-34aba. The water tables at the observation points were also lower in 1969 than in 1968. In August and September they averaged about two feet lower.

Low flow measurements in the drainage ditches indicated that Pool 6 has caused no increase in seepage into the ditches where observed.

During the first half of 1969 on Hartman Bottoms the water tables and piezometric surfaces were generally at a lower elevation than the pool at Project Mile 242.4, and averaged about 3 feet higher than static pool stage, elevation 338. During the fall months the piezometric surface was from 1 foot above to 1 foot below static pool stage. The water table at several observation points was about 2 feet below static pool stage in August, September, and October. This was apparently the result of evapotranspiration during these months. Some areas were not planted and some had delayed planting in 1969 because of shallow water tables.

On McLean Bottoms the piezometric surfaces and water tables were as much as 2 feet higher at their peak in June 1969 than in 1968. These higher peaks were attributed to two consecutive years of high pool stages and above normal rainfall. During the last part of the growing season the piezometric surfaces were similar in both years. The piezometric surfaces gradually raised from 2 to 3 feet during the first half of 1969 and gradually lowered about 2 feet during the last half.

Water table was observed at 42 observation points, but had no influence on crops at 15 of these. The crop was benefited at 16 observation points by the water table, and the effects were detrimental at 11 points. No damage occurred at the points on Fourche Island. Crops were damaged at 5 points on Hartman Bottoms and 6 points on McLean Bottoms. Of the 11 areas where damage was observed, 6 were not planted, 4 had delayed planting, and 1 produced a volunteer crop, all because the water table was too shallow. Crop damage occurred at 3 points from surface ponded water. Crops were benefited at 16 observation points by use of water tables in the root zone.

Pool 6 stages had no significant influences on the piezometric surfaces or water tables over most of the area that was observed on Fourche Island. Most of them were actually higher in the year before closure than in the year following closure. Pool 6 stages caused no increase in seepage into the drainage ditches on Fourche Island.

Piezometric surfaces on Hartman Bottoms will be two to five feet higher than static pool stage during the dormant winter and spring months, but will be one foot above or below static pool stage during the time when plants are growing actively and rainfall is deficient. Water tables will be up to two feet below static pool stage during this time.

Land where water tables are less than about $\frac{1}{2}$ foot deep will generally not be planted. Because of this, some areas were not planted and on some areas planting was considerably delayed and resulted in lower production. At one location volunteer wheat and soybeans grew well to maturity with a water table no more than 0.5 foot below the surface. Crops benefited from the water table where it was between about one and five feet deep, particularly from mid July to mid August.

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3. Blocked drainage

a. Summation of surface drainage reach reports

Surveys and investigations of surface drainage problems and agricultural drainage needs were extended to all areas affected by ARMPP. Twelve reach reports were prepared covering the area adjacent to ARMPP from the junction of White River and Arkansas Post Canal to Lock and Dam No. 14 in Oklahoma. Major effects for the remaining Oklahoma reaches were listed in watershed investigation reports. A single reach report includes ARMPP affected areas between successive locks and dams as listed in Table 32, Pages 207 - 212 .

Reports include, by watersheds, such surface drainage features related to ARMPP as:

(1) Drainage outlet structure locations, number, size, elevations, post-project capacities, structure modifications, and/or new outlets and diversions proposed.

(2) Map delineations of areas affected by navigation pools and/or 5-year recurrence interval post-project flood elevations.

(3) Project land acquisition criteria are listed by watersheds. Blocked or impaired drainage due to ARMPP amounted to about 77,500 acres, affecting 48 watershed areas in 13 of the 17 reaches. Significant areas were affected in 37 watersheds while only very minor drainage impairment occurred in the remaining 11 watersheds. About 62 percent of the affected area is located in 22 watersheds in reaches occupied by the high, multiple-purpose Dardanelle, Ozark, and Kerr reservoirs. Six of the 37 materially affected watersheds are PL-566 projects, 12 are potentially feasible upstream projects, and 19 were classified not feasible under pre-project conditions. Four potential upstream watersheds were classified as unfeasible due to installation of ARMPP and potential benefits were reduced on at least three additional watersheds. Loss of the 77,500 acres reduced the size, importance, and potential benefits in at least 37 watersheds.

b. Remedial measures

The Corps of Engineers recognized that some areas would be adversely affected by the ARMPP. Areas severely affected were usually purchased. Remedial measures for adversely affected surface drainage were planned if found to be more economical than either land acquisition or purchase of flowage easements. The Corps studied several alternative solutions for the more important affected areas.

Remedial measures included as a part of ARMPP are: (1) 3 diversion channels to provide proper drainage outlets, (2) 3 reservoirs for fish and wildlife mitigation measures, (3) 3 levee and pumping plant systems, (4) 1 levee system with drainage structures, and (5) 3 low water weirs to protect existing water supplies.

Real estate guide taking lines for purchase of the 77,500 acres affected by blocked or impaired drainage in the upper reaches of Dardanelle, Ozark, and Kerr reservoirs were determined on the basis of the envelope of backwater effects with the 50-year sediment profile, plus freeboard. Guide taking lines for other reaches were usually 3 feet above normal

pool elevations in the lower reaches of navigation pools and the 5-year modified flood profiles in the upper reaches. More detailed land acquisition criteria are contained in the lock and dam design memoranda. Location of the areas where drainage is impaired is shown by subwatersheds in Table 32, Pages 207 - 212 .

The difference between the estimated total 213,600 acres purchased and the 77,500 acres acquired due to impaired drainage represents lands needed for structures, maintenance, roads, horizontal shoreline control, recreation and wildlife areas, and for other project purposes.

The Plum Bayou Watershed is an area where remedial drainage measures were made. Approximately 7 miles of diversion channel was planned to outlet below Lock and Dam No. 4. Two drainage structures in the upper part of the watershed will be altered, as a remedial drainage measure. These structures are in Reach No. 5.

The existing weir on Cadron Creek would be inundated by Navigation Pool No. 8, thus rendering the Conway, Arkansas, water supply useless. A remedial weir is being constructed. The impoundment will be fenced as required by the Arkansas State Board of Health.

McLean Bottom, Hartman Bottom, and the Prairie Creek area west of Russellville are other areas where remedial measures were constructed, or have been planned. Hartman Bottom consists of two areas, Upper Hartman Bottom and Lower Hartman Bottom. A protective levee and five drainage structures were constructed to protect Lower Hartman Bottom. The need for levee protection from surface flooding of Upper Hartman Bottom is to be determined on the basis of observed sediment deposits in the Dardanelle Reservoir, Reach No. 10.

A protective levee was constructed around the turkey processing plant at Ozark, Arkansas, Reach No. 12, and a pumping plant was also installed to pump surface runoff from within the levee.

The existing drainage structure in the Hollis Lake area, Reach No. 13, will be blocked and a new drainage structure will be constructed to discharge surface runoff from the Flat Rock Creek-Hollis Lake area to below Lock and Dam No. 13.

In Oklahoma, remedial drainage measures generally consist of acquisition of land, including flowage easements. Spoil material from dredging operations will be placed in such a manner that drainage outlets will not be blocked. Spoil material will also be placed in low areas.

The west segment of Mud Slough, in the Oklahoma portion of Reach No. 13, intercepts the left (north) abutment access road from Lock and Dam No. 14. To discharge surface drainage runoff from this segment of Mud Slough into Navigation Pool No. 14 would require a bridge at the access road intersection. In lieu of constructing the bridge, the Corps of Engineers plan to divert Mud Slough to outlet into Navigation Pool No. 13.

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4. Upstream watershed projects

a. Summation of watershed investigation reports

(1) Public Law 566 projects

There are currently 36 PL-566 type watershed projects, including Six Mile Creek (Pilot), in the ARMPP study area outlined on Figure 3 in Arkansas and Oklahoma. Construction is complete on three projects, six are under construction, and six have been approved for construction. Nineteen watersheds have been authorized for planning and work plans are complete on two additional watersheds. Pertinent data relative to these 36 watersheds are shown in Table 32, Pages 207-212 .

(2) Potential upstream projects

Watershed preliminary investigation reports were made on 99 watersheds, 70 in Arkansas and 29 in Oklahoma. Of the 70 potential Arkansas watersheds, 33 were classified as feasible and 37 not feasible. Of the 29 watersheds in Oklahoma, 14 were classified as feasible and 15 not feasible. Two projects in Arkansas and two in Oklahoma were classified not feasible due to the ARMPP.

(3) Basin studies

A Type IV Comprehensive River Basin study was completed on the entire Poteau River segment in 1966. A Type IV Comprehensive River Basin study is currently in progress on the Bayou Meto segment of the Arkansas River basin.

b. Effect of navigation structures on potential and existing upstream projects

As indicated under the section on blocked drainage, areas on which blocked or impaired drainage occurred due to ARMPP totaled about 77,500 acres, affecting 48 watershed areas in 13 of the 17 lock and dam reaches. Significant areas were affected in 37 watersheds and minor drainage impairment occurred in the remaining 11 watersheds. About 62 percent of the affected area is located in 22 watersheds in reaches occupied by the high, multiple-purpose Dardanelle, Ozark, and Kerr reservoirs. Six of the 37 materially affected watersheds are PL-566 projects, 12 are potentially feasible upstream projects, and 19 were classified not feasible under pre-project conditions.

Four potential upstream watersheds were classified as unfeasible due to installation of ARMPP and potential benefits were reduced on at least three additional watersheds. Loss of the 77,500 acres reduced the size, importance, and potential benefits in at least 37 watersheds. Pertinent data for each of the 135 watersheds outlined on Figure 3 are listed by reaches in Table 32. Items included are watershed name, number, total area, floodplain and/or bottomland area, blocked or impaired drainage, approximate ARMPP area purchased in fee and by easement, preliminary investigation reports made, and status of PL-566 projects.

The reach and watershed investigation reports will be used to guide future upstream watershed activity, including planning approval, technical details of planning, construction, and operation.

(Text Continued Page 213)

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ARKANSAS RIVER MULTIPLE-PURPOSE PROJECT
ARKANSAS AND OKLAHOMA
STATUS OF UPSTREAM WATERSHEDS

Table 32
(Sheet 1 of 6)

NUMBER ARMPP	NUMBER CNI	WATERSHED NAME	Total Acres	Floodplain Acres (or bottom-land - B)	Agricultural Drainage Impaired or Blocked By ARMPP: Acres	Agricultural Drainage Impaired or Blocked By ARMPP: Navig. Pool Number	Area Purchased by ARMP Project-Acres (Approx.): Fee	Area Purchased by ARMP Project-Acres (Approx.): Ease-ment	Area Purchased by ARMP Project-Acres (Approx.): Total	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project Not Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project Same as pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project Less than pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project Not Feasible	PROGRESS IN PL-566 WTSH. PROJ.: Auth. for Planning	PROGRESS IN PL-566 WTSH. PROJ.: Work Plan Complete	PROGRESS IN PL-566 WTSH. PROJ.: Auth. for Oper., or Const. Complete
		ARKANSAS															
REACH 1 (Mississippi River to Lock No. 2)							207	91	298								
1	1-218	Area Between Levees, Mouth of River to L & D No. 6	134,730	(134,730 B)	-	-					X			X			
REACH 2 (Lock No. 2 to Lock & Dam No. 3)							7,884	11,980	19,864								
4	1-217	Little Post Bayou	9,260	(9,260 B)	489	2				X*			X				
5	1-216	Moore Bayou	5,860	1,837	364	2				X*			X				
6	laa-1	Mill Bayou	125,440	41,500	5,600	2									X 1		
7	laa-3	Bayou Meto	242,560	120,000	550	2									X 1		
8	laa-5	Bayou Two Prairie	144,000	28,700	0	2									X 1		
16	laa-6	Upper Bayou Meto	124,800	15,200	0	2									X 1		
10	laa-4	Upper Little Bayou Meto	94,080	31,000	0	2									X1		
9	laa-2	Lower Little Bayou Meto	188,800	34,200	45	2									X1		
REACH 3 (Lock & Dam No. 3 to Lock & Dam No. 4)							428	2,154	2,582								
None																	
REACH 4 (Lock & Dam No. 4 to Lock & Dam No. 5)							1,011	2,287	3,298								
14	1-209	Plum Bayou	130,560	(130,560 B)	536	4									X		
11	1-215	Waterloo Drainage District	41,000	(41,000 B)	0	4									X		
12	1-214	Tucker Lake Levee & Drainage District	4,000	(4,000 B)	45	4				X*		X					
17	1-213	Caney Bayou (Pine Bluff Arsenal)	39,326	(39,326 B)	0	4					X			X			
REACH 5 (Lock & Dam No. 5 to Lock & Dam No. 6 (David D. Terry))							706	3,202	3,908								
18	1-212	Love Creek	4,000	(4,000 B)	0	5					X			X			
19	1-211	Tar Camp Creek	9,478	275	0	5					X			X			
20	1-210	Harris Bayou	19,200	2,260	0	5					X			X			
21	1-207	Pennington Bayou	77,506	(17,255 B)	0	5				X		X					

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Table 32 continued
(Sheet 2 of 6)

NUMBER ARMPP	NUMBER CNI	WATERSHED NAME	Total Acres	Floodplain Acres (or bottom-land - B)	Agricultural Drainage Impaired or Blocked By ARMPP: Acres	Agricultural Drainage Impaired or Blocked By ARMPP: Navig. Pool Number	Area Purchased by ARMP Project-Acres (Approx.): Fee	Area Purchased by ARMP Project-Acres (Approx.): Ease-ment	Area Purchased by ARMP Project-Acres (Approx.): Total	PRELIMINARY INVESTIGATION REPORTS MADE: Pre- Project: Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Pre- Project: Not Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Post- Project: Same as pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post- Project: Less than pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Not Feasible	PROGRESS IN PL-566 WTSH. PROJ.: Author. for Planning	PROGRESS IN PL-566 WTSH. PROJ.: Work Plan Complete	PROGRESS IN PL-566 WTSH. PROJ.: Author. for Oper. or Constr. Complete
22	1-206	Fourche Bayou	14,322	(12,052 B)	0	5											X 3/
13	1-208	Beaver Dam Bayou	10,624	(10,624 B)	0	5									X		
15	1-209a	Ashley Bayou	27,516	(27,516 B)	470	6				X			X				
REACH 6 (L & D No. 6 to L & D No. 7)							677	1,155	1,832								
23	1-205	Fourche Creek (Little Rock)	108,160	4,600	0	6					X			X			
24	1-204	North Little Rock City Drains	13,670	3,575	0	6					X			X			
26	1-203	White Oak Bayou	27,193	1,306	0	6					X			X			
REACH 7 (L & D No. 7 to L & D No. 8)							473	4,051	4,524								
25	1-202	Little Maumelle River	56,320	2,677	1,202	7					X			X			
27	1-201	Palarm Creek (South Fork)	7,774	3,477	1,280	7				X				X 2/			
29	1-200	Maumelle River	89,206	647	451	7					X			X			
30	1-198	Mill Bayou	8,400	(2,600 B)	0	7				X		X					
31	1-197	Beaverdam Creek	8,285	(2,533 B)	0	7				X*		X					
32	1-195	Faulkner County Levee Dist. No.2	3,545	(2,518 B)	0	7				X*		X					
33	1-194	Tupelo Bayou	25,880	3,390 (7,100 B)	0	7											X
28	1-199	Palarm Creek (North Fork)	98,455	7,351 (12,879B)	225	7					X			X 2/			
28a	1-199a	Little Cypress Creek	10,000	700	0	7				X		X					
38	1-196	Ross Hollow	5,952								X			X			
39	lz-2	South Fourche La Fave River	248,990	23,400	7,100	7											X
40	lz-1	Mill Creek	16,143	1,562	0	7				X		X					
41	1-193	Taylor Creek	5,250	420	0	7				X*		X					
42	1-192	Perry County Drainage Dist. No.1 (Ouachita Creek)	4,250	745 (1,405 B)	0	7											X 3/
REACH 8 (L & D No. 8 to L & D No. 9)							254	3,550	3,804								
51	1-189	Cypress Creek	41,631	190 (3,360 B)	0	8				X		X					
35	ly-1	Lower Cadron Creek	81,000	7,300	3,200	8									X		
34	ly-2	East Fork Cadron Creek	197,760	14,700	0	8									X		
36	ly-3	North Fork Cadron Creek)	Combined												X		
37	ly-4	Upper North Fork Cadron Creek)	208,640	10,500	0	8									X		
49	1-188	Conway Co. Levee District No.6	4,768	3,140	0	8				X*		X					
48	1-190	Portland Bottoms	8,896	8,896	125	8				X				X			
44	1-184	Lower Roint Remove Creek	37,223	3,963	0	8				X		X					
43	1-191	Conway Co. Levee Dist. No. 8 (Gap Creek)	13,693	2,087 (4,302 B)	673	8					X			X			
47	1-187	Conway Co. Levee Dist. Nos. 1 & 10 (Miller Bayou)	14,000	9,200	0	8				X*		X					
56	1-181	Horsehead Branch (Kuhn Bayou) (R.C. & D. Project)	11,500	7,500	0	8										X	

Table 32
(Sheet 3 of 6)

NUMBER ARMPP	NUMBER CNI	WATERSHED NAME	Total Acres	Floodplain Acres (or bottom-land - B)	Agricultural Drainage Impaired or Blocked By ARMPP: Acres	Agricultural Drainage Impaired or Blocked By ARMPP: Navig. Pool Number	Area Purchased By ARMP Project-Acres (Approx.): Fee	Area Purchased By ARMP Project-Acres (Approx.): Ease-ment	Area Purchased By ARMP Project-Acres (Approx.): Total	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Not Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Same as pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Less than pre-project Benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Not Feasible	PROGRESS IN PL-566 WTSH. PROJ.: Author. for Planning	PROGRESS IN PL-566 WTSH. PROJ.: Work Plan Complete	PROGRESS IN PL-566 WTSH. PROJ.: Authorization for Operations or Construction Complete
46	1-185	West Fork Point Remove Creek	201,312	18,929	0	8											X
45	1-186	East Fork Point Remove Creek	87,865	6,096	0	8											X
		REACH 9 (L & D No. 9 to L & D No. 10 (Dardanelle Dam))					227	1,361	1,588								
50	1-183	Conway Co. Levee and Drainage Dist. No. 1 (Martin Lake)	4,500	200 (730 B)	220	9					X			X			
55	1-182	Dowdle Bend	3,520	(2,080 B)	0	9				X*		X					
54	1x-1	Cedar Creek	8,492	0	0	9					X			X			
53	1x-2	Carden Bottom Drainage Dist.No.2	10,840	8,250	0	9				X		X					
52	1x-3	Rose Creek	37,120	0	0	9					X			X			
61	1x-4	Petit Jean River	130,440	34,000	0	9					X			X			
63	1x-6	Cedar-Piney Creeks	29,400	3,250	0	9											X
62	1x-5	Big and Little Chickalah Creeks	49,975	3,700	0	9				X		X					
64	1-176	Smiley-Pin-Harris Creeks	32,560	3,390	0	9									X5|		
66	1-174	Whig Creek	9,664	480	0	9				X*		X					
65	1-175	Holla Bend Drainage & Levee Dist. No. 2	11,520	(5,200 B)	0	9					X			X			
60	1-177	Holla Bend National Wildlife Refuge	7,806	(7,806 B)	0	9					X			X			
59	1-178	Galla Creek	29,440	2,513	0	9											X
58	1-179	Lake Atkins	6,836	(752 B)	0	9					X			X			
57	1-180	Pope Co. Levee Dist. No. 2	4,500	740 (3,120 B)	0	9				X*		X					
		REACH 10 (L & D No. 10 (Dardanelle Dam) to L & D No. 12 (Ozark Dam))					44,778	6,354	51,132								
69	1-171	Hayes Creek	9,856	(920 B)	920	10					X			X			
70	1-170	Delaware Creek	26,108	4,014	2,869	10					X			X			
71	1-167	Shoal Creek	81,536	3,060	2,380	10					X			X			
78	1-163	Six Mile Creek	164,627	12,192	2,578	10											X3|
79	1-160	Smith and Moore Creeks	16,154	680	630	10					X			X			
80	1-161	Pond Creek	8,160	45	0	10				X		X					
75	1-164	Spadre Creek & Horsehead	165,792	11,127	7,191	10										X4|	
77	1-162	Hegwood-Lower Six Mile Creek	21,120	10,500	1,266	10				X				X			
76	1-165	Cane Creek	34,280	2,200	930	10				X				X			
72	1-166	Cabin Creek	17,280	220 (4,452 B)	198	10					X			X			
74	1-169	Little Piney Creek	105,600	4,800	80	10					X			X			
73	1-168	Big Piney Creek	243,200	6,628	2,588	10					X			X			
68a	1-172a	Prairie-Shiloh Creek	10,710	885	354	10				X				X			
68	1-172	Illinois Bayou	250,880	8,000	8,155	10					X			X			
67	1-173	McCoy Creek	19,370	1,100	0	10				X		X					

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Table 32 continued
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NUMBER ARMPP	NUMBER CNI	WATERSHED NAME	Total Acres	Floodplain Acres (or bottom-land - B)	Agricultural Drainage Impaired or Blocked By ARMPP: Acres	Agricultural Drainage Impaired or Blocked By ARMPP: Navig. Pool Number	Area Purchased By ARMP Project-Acres (Approx.): Fee	Area Purchased By ARMP Project-Acres (Approx.): Ease-ment	Area Purchased By ARMP Project-Acres (Approx.): Total	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Not Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Same as pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Less than pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Not Feasible	PROGRESS IN PL-566 WTSH. PROJ.: Author. for Planning	PROGRESS IN PL-566 WTSH. PROJ.: Work Plan Complete	PROGRESS IN PL-566 WTSH. PROJ.: Authorization for Operations or Construction Complete
REACH 12		(L & D No. 12 (Ozark Dam) to L & D No. 13)					3,987	23,313	27,300								
82	1-155	Mill Creek (Franklin Co.)	13,286	650	0	12					X			X			
83	1-158	River Ridge	8,640	900	0	12					X			X			
89	1-154	Onion-Big Creek	85,800	1,600	315	12				X		X					
88	1-148	Vache Grasse Creek	75,776	4,835	0	12									X		
100	1-147	Little Vache Grasse	10,880	400	0	12					X			X			
103	1-149	Mays Branch-Rose Lake	12,736	2,200 (5,000 B)	0	12				X		X					
87	1-150	Mays Branch	6,466	1,500 (3,656 B)	130	12				X*		X					
104	1-152	Clear Creek))) Combined								X		X					
105	1-153	Jones Fork)	160,000	6,800	0	12				X		X					
86	1-151	Little Clear Creek	14,580	1,183	0	12									X		
85	1-156	Little Mulberry Creek	34,214	1,565	0	12											X
84	1-157	Mulberry River	320,000	10,200	2,500	12					X			X			
81	1-159	Ozark Highlands (White Oak)	74,880	5,891	0	12				X		X					
REACH 13		(L & D No. 13 to L & D No. 14) Part.					299	2,124	2,423								
99	1-146	Massard Creek	10,240	547	140	13					X			X			
98	1w-12	Mill Creek	7,627	596	0	13					X			X			
90 6/	1w-10	James Fork 8/	104,454	3,588	0	13									X		
91 6/	1w-1	Poteau River	187,460	16,122	0	13											X
101	1-144	Fort Smith (Town Drains)	5,100	716	476	13					X			X			
106 6/	1-142	Lower Lee Creek	107,500	5,100	0	13					X			X			
107	1-143	Upper Lee Creek	107,520	2,850	0	13					X			X			
102	1-145	Flat Rock Creek	19,000	2,400 (4,400 B)	0	13									X		
Sub-Totals - Arkansas		101	6,010,268	612,940 (505,136 B)	56,275	--	60,931	61,622	122,553	33	37	25	3	42	18	2	11

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Table 32 continued
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NUMBER ARMPP	NUMBER CNI	WATERSHED NAME	Total Acres	Floodplain Acres (or bottom-land - B	Agricultural Drainage Impaired or Blocked By ARMPP: Acres	Agricultural Drainage Impaired or Blocked By ARMPP: Navig. Pool Number	Area Purchased By ARMP Project-Acres (Approx.): Fee	Area Purchased By ARMP Project-Acres (Approx.): Ease-ment	Area Purchased By ARMP Project-Acres (Approx.): Total	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Not Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Same as pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Less than pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Not Feasible	PROGRESS IN PL-566 WTSH. PROJ.: Author. for Planning	PROGRESS IN PL-566 WTSH. PROJ.: Work Plan Complete	PROGRESS IN PL-566 WTSH. PROJ.: Authorization for Operations or Construction Complete
		OKLAHOMA															
REACH 13		Part.					6	51	57								
97 7/	lw-11	Spiro and Bonanza Laterals 8/	52,154	700	0	13					X			X			
94 7/	lw-8	Combined Creeks 8/	118,272	3,205	0	13				X		X					
93	lw-2	Heavener Laterals))) Combined 8/									X			X			
95	lw-7	Poteau Laterals)	62,740	800	0	13					X			X			
92 7/	lw-3	Black Fork Creek 8/	133,414	5,872	0	13				X		X					
119	lw-4	Holston-Reichert-Conser Creek 8/	97,792	1,500	0	13					X			X			
120	lw-5	Fourche-Maline Creek	175,360	14,654	0	13											X
118	lw-6	Caston-Mountain Creeks 8/	47,853	2,668	0	13											X
117	lw-9	Brazil Creek 8/	152,100	3,352	0	13				X		X					
109 7/	1-140	Garrison Creek	21,521	7,576	0	13									X		
108	1-141	Little Lee Creek	76,877	2,331	0	13					X			X			
REACH 14		(L & D No. 14 to L & D No. 15 (Robert S. Kerr))					972	380	1,352								
96	1-138	Cache Creek	69,120	3,103 (13,828 B)	0	14				X		X					
115	1-137	Cache Creek Bottom	12,535	2,709 (9,720 B)	0	14											X
110	1-139	Big Skin Bayou	119,014	6,171 (17,778 B)	0	14				X		X					
REACH 15		(L & D No. 15 to L & D No. 16 (Webbers Falls))					55,237	2,089	57,326								
116	1-135	San Bois Creek	205,000	15,000	0	15				X		X					
135	lv-59	Lower Canadian River	96,691	2,505 (18,120 B)	3,954	15					X			X			
114	1-134	Little San Bois Creek	42,368	1,332 (4,862 B)	410	15					X			X			
122	1-131	Dirty Creek	222,720	16,149	592	15				X		X					
121	1-132	Georges Fork	38,920	2,944	0	15				X		X					
113	lu-9	Lower Illinois River	33,664	275 (3,322 B)	687	15					X			X			
112	1-133	Vian Creek	75,500	5,359 (9,973 B)	8,200	15					X			X			
111	1-136	Sallisaw Creek	185,280	12,771	1,525	15											X

Table 32 continued
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NUMBER ARMPP	NUMBER CNI	WATERSHED NAME	Total Acres	Floodplain Acres (or bottom-land - B	Agricultural Drainage Impaired or Blocked By ARMPP: Acres	Agricultural Drainage Impaired or Blocked By ARMPP: Navig. Pool Number	Area Purchased By ARMP Project-Acres (Approx.): Fee	Area Purchased By ARMP Project-Acres (Approx.): Ease-ment	Area Purchased By ARMP Project-Acres (Approx.): Total	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Pre-Project: Not Feasible	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Same as pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Less than pre-project benefits	PRELIMINARY INVESTIGATION REPORTS MADE: Post-Project: Not Feasible	PROGRESS IN PL-566 WTSH. PROJ.: Author. for Planning	PROGRESS IN PL-566 WTSH. PROJ.: Work Plan Complete	PROGRESS IN PL-566 WTSH. PROJ.: Authorization for Operations or Construction Complete
REACH 16		(L & D No. 16 to L & D No. 17)					15,900	4,160	20,060								
123	1-130	Spaniard Creek	40,000	1,265	3,008	16				X				X 2/			
124	1-127	Coody Creek	35,328	1,200	30	16				X		X					
128	1-126	Pecan Creek	38,300	668	34	16					X			X			
127	1t-42	Flower Creek	4,518	96	0	16					X			X			
126	1-128	Manard Bayou	50,200	1,359	64	16					X			X			
125	1-129	Greenleaf Creek	102,963	4,279	2,562	16				X				X 2/			
REACH 17		(L & D No. 17 to L & D No. 18)					6,709	833	7,542								
130	1s-25	Bull Creek Laterals	130,790	5,322	126	17					X			X			
REACH 18		(L & D No. 18 to Head of Navigation)					3,992	747	4,739								
129	1s-26	Adams-Coal Creek	156,160	7,972	75	18 & 17					X			X			
134	1s3-3	Lower Bird Creek	244,050	39,501	0	18				X		X					
132	1s-23	Lower Middle Verdigris	90,880	964	0	18					X			X			
133	1s2-12	Lower Caney River	137,741	21,312	0	18				X		X					
131	1s-24	Dog Creek	83,840	4,018	0	18				X		X					
Sub-Totals - Oklahoma		34	3,153,665	198,932 (77,603 B)	21,267	--	82,816	8,260	91,076	14	15	12	0	17	1	0	4
TOTALS - Arkansas and Oklahoma		135	9,163,933	811,872 (582,739 B)	77,542	--	9/ 143,747	69,882	213,629	47	52	37	3	59	19	2	15

1/ Type IV River Basin Study in progress
2/ Not Feasible due to ARMPP
3/ Construction Complete
4/ Applies to Spadra Creek, 138,400 acres, only
5/ Plannin suspended
6/ Part in Oklahoma
7/ Part in Arkansas
8/ Included in Poteau River Basin Type IV Study Completed in 1966
9/ Areas as of the date of watershed investigation reports. Additional purchases have been made in some watersheds. Total as of September 1969 was 148,565 acres in fee.

* Considered too small for PL-566 Project Development

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Other possible detrimental effects of ARMPP include:

(1) Increase in area and duration of flooding at certain elevations under initial ARMPP operating conditions, prior to any sedimentation, in the upper reaches of Ozark Reservoir.

(2) Sediment deposits in upper and/or fringe areas of static pools may form plugs in or reduce life of lateral inflowing streams and channels. (3) Future land use and agricultural inputs in anticipated sediment deposit areas may be affected.

(4) Increase in soil salt content.

Remedial measures, in the form of fee or easement purchase of affected areas will be made initially for most of these conditions. Experienced project operation will determine whether additional measures will be needed.

The Six Mile Creek (Pilot) Watershed Project, including flood plain common with the Arkansas River, is not protected from Arkansas River flooding and ARMPP does not include protective measures for the area. The Six Mile Creek project has a constructed diversion channel as its only outlet, discharging directly into the Arkansas River at river mile 300.9 (1940 survey). The elevation of the power pool of the Dardanelle Reservoir, Reach No. 10, is 338.0 feet msl and backwater from the reservoir at this elevation extends upstream in the Six Mile Creek Watershed constructed channels for about 4 miles, and will also inundate a portion of the flanking agricultural land in the watershed. The Corps of Engineers has acquired 2,578 acres lying at or below elevation 358.0 feet that are expected to be inundated by the pool elevation of 338.0 feet or to be flooded at 5-year or more frequent intervals. In addition, 1,962 acres lying between the elevation of 5-year frequency flooding, elevation 358.0 feet and elevation 364.0 feet, the elevation of approximately 50-year frequency flooding, have been covered with flowage easements.

Backwater at elevation 364.0 feet will extend upstream in the Six Mile Creek Channel for a distance of about 14 miles from the river and involve most of the improved channels that have been installed. Lands acquired by the Corps of Engineers are removed from private ownership and agricultural use and lands covered with flowage easements will probably not be developed intensively.

A work plan is complete on the Spadra Creek segment of Horsehead and Spadra Creeks Watershed. Spadra Creek outlets into the Arkansas River, Reach No. 10, at river mile 282.6 (1940 survey). A large part of the bottomland in the lower reach of Spadra Creek has been acquired by the Corps of Engineers because it will be either permanently inundated at the pool elevation of 338.0 feet or flooded to elevation 349.0 feet, the expected 5-year frequency of flooding elevation. An area of 5,828 acres was acquired to elevation 349.0 feet. Flowage easements were obtained on an additional 552 acres to an expected 50-year frequency of flooding to elevation 354.0 feet.

Project mitigation measures were planned where installation, operation, and maintenance represented a more economical alternative to land acquisition. In the Dardanelle, Ozark, and Kerr reservoir reaches, approximately 51,000 acres, 27,300 acres, and 57,300 acres, respectively,

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were removed from the agricultural base of the area by fee and easement acquisition.

5. Agricultural Economy

The installation of ARMPP involved the Federal acquisition of some 66,000 acres in Arkansas and 83,000 acres in Oklahoma. Cropland was reduced by about 39,000 acres, (Table 33). In the current situation, the gross value of lost production amounted to only two-tenths of one percent of gross income from agriculture for the study area, and seven-tenths of one percent of gross income from crops.

Table 33--Acres and total crop value with and without ARMPP
Present and 2000

	Acreage			Total Value		
	Without ARMPP	With ARMPP	Difference	Without ARMPP	With ARMPP	Difference
	Thousand Acres			Thousand Dollars		
Present	1,314	1,275	39	90,621	89,668	953
2000	1,303	1,267	36	129,065	127,085	1,980

In the year 2000, it is estimated that the acreage of crops would be reduced 36,000 and that the value of lost production would amount to about $2 million. The decrease in acreage is mainly due to the shift of land from agricultural to non-agricultural uses.

Since the effects of the project were localized, the impact on crops varied. Corn, sorghum, and wheat production was decreased by four or more percent as a result of ARMPP.

Those crops most affected by the project are grown more in the area west of Little Rock, particularly in Oklahoma. Soybeans, cotton, and rice production were reduced by two percent or less.

Table 34 shows the production of crops for ARMPP study area with and without ARMPP for present conditions.

Table 34--Crop production without and with ARMPP, present condition

Crop	Unit	Without ARMPP	With ARMPP
		-----Thousands-----	
Corn	Bu.	1,027	967
Sorghum	Bu.	1,447	1,393
Wheat	Bu.	3,509	3,365
Hay	Ton	164	159
Oats	Bu.	1,074	1,048
Soybeans	Bu.	14,087	13,820
Cotton	Lb.	58,396	57,794
Rice	Lb.	605,824	605,751

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This represents a combination of effects. The purchase of land and its removal from production results in a decrease in production of all crops. This is countered in part by the beneficial effects of the raised water table. For most crops the net effect is a small decrease.

The localized effects of ARMPP were somewhat more significant. The effects of ARMPP are for the most part localized around the two high lift structures, Dardanelle in Arkansas and Robert S. Kerr in Oklahoma. About 70 percent of the land purchased in Arkansas and almost 85 percent of that purchased in Oklahoma were associated with these two structures. This puts the major direct effect of ARMPP land purchase in Franklin, Johnson, Logan, Pope, and Yell Counties in Arkansas, and Haskell, Leflore, Muskogee, and Sequoyah Counties in Oklahoma. In these counties total value of production decreased about $60 for each acre of soybeans and $120 for each acre of cotton taken out of production. These nine counties had a total crop income of only $12 million in 1964. The loss of production value from soybeans alone accounted for about 6 percent of total value of production.

Raising of the water table and increases in yields occurred with several of the structures. Counties in which this occurred were Arkansas, Conway, Desha, Jefferson, Lincoln, Lonoke, Pulaski, and Sebastian in Arkansas, and Wagoner in Oklahoma. These counties, particularly in Arkansas, are those with higher agricultural income.

Table 35 reports the data related to the situation representing the addition of all feasible upstream projects to ARMPP. This includes increased yields as a result of flood protection and drainage on about 65,000 acres. The slight increase in total acreage comes from project associated forest clearing. In 2000, the total value of production would be about $15 million greater.

Table 35--Acres and total value of production without ARMPP and with ARMPP and all feasible upstream projects, 2000

	Area			Total Value		
	With ARMPP	With Upstream	Difference	With ARMPP	With Upstream	Difference
	-------Thousand Acres-------			------Thousand Dollars------		
Present	1,275	-	-	89,668	-	-
2000	1,267	1,268	1	127,085	142,092	15,007

Table 36 shows by sub-area the production of major crops. Soybeans, rice, and cotton would be the crops most affected by upstream development.

The Bayou Meto sub-area would be the area most affected by upstream development. This includes portions of Arkansas, Jefferson, Lonoke, and Pulaski Counties. In addition, the areas benefited by the Plum Bayou, Ashley Bayou, and Pennington Bayou projects lie south and east of Little Rock in Pulaski and Lonoke counties. All of these have high portions of land in high productivity SRG's and respond well to development. The other areas in Arkansas have small areas of cropland that would be benefited.

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Table 36--Crop Production ARMPP Study Area,
with ARMPP, and without ARMPP and Upstream Projects, 2000 by subarea

Crop	Unit	Mainstem		Bayou Meto		FPP		Cadron		Oklahoma		Total 1/	
		With ARMPP	With upstream	With ARMPP	With upstream	With ARMPP	With upstream	With ARMPP	With upst.	With ARMPP	With upstream	With ARMPP	With upst.
		000	000	000	000	000	000	000	000	000	000	000	
Corn	Bu.	814	864	--	--	412	412	190	190	442	442	1,857	1,912
Sorghum	Bu.	128	131	--	--	73	74	18	18	2,752	2,774	2,972	2,997
Wheat	Bu.	556	611	110	144	128	128	71	71	4,362	4,404	5,227	5,357
Oats	Bu.	923	1,028	299	374	90	90	35	35	282	282	1,601	1,810
Hay	Bu.	52	53	12	12	16	16	15	15	145	146	239	242
Soybeans	Bu.	5,534	6,081	11,385	14,384	292	295	300	315	2,014	2,031	19,522	23,105
Cotton	Lb.	41,286	44,627	31,590	39,069	1,298	1,310	703	724	7,907	7,970	82,784	93,700
Rice	Lb	238,856	238,856	539,674	599,948	31,714	32,033	--	0	--	--	810,244	870,837

1/ Does not add due to rounding

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In Oklahoma, the three largest projects, in terms of cropland affected, are Lower Bird Creek in Tulsa County, Big Skin Bayou in Sequoyah County, and Dirty Creek in Muskogee County. The largest effects in Oklahoma would be felt in sorghum and wheat.

To maintain its historical share of the nation's food and fiber production in the ARMPP study area, the year 2000 would have to supply the amounts of the indicated crops in Table 37.

With the current land use patterns in 2000, in either of the situations analyzed, the area can produce its share of corn, sorghum, oats, hay, cotton, and rice. More wheat and soybeans will have to be produced than indicated by present patterns of production to meet their requirements. The addition of upstream projects is one way to obtain the increased production.

Also, it must be noted that under each of the situations analyzed, there were approximately 350,000 acres of cropland idle or being used for pasture, that could be converted to crop production at little cost. However, much of this is land of lower productivity. Too, pasture and range, as well as forest land, could be converted to crop production should demand increase sufficiently to overcome the conversion cost.

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Table 37--Estimates of ARMPP Study Area: Projected contribution to national production based on historical shares and estimated production with ARMPP and ARMPP with upstream projects added, 2000.

Crop	Unit	2000		
		ARMPP Area Share	With ARMPP	With Upstream Projects
		Thous.	Thous.	Thous.
Corn	Bu.	767	1,857	1,912
Sorghum	Bu.	2,488	2,971	2,997
Wheat	Bu.	5,944	5,227	5,357
Oats	Bu.	934	1,631	1,810
Hay	Tons	224	239	242
Soybean	Bu.	24,648	19,522	23,105
Cotton	Lbs.	46,841	82,784	93,700
Rice	Lbs.	579,122	810,243	870,837

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SUMMARY AND CONCLUSIONS

Watershed investigations were made of each of the 135 upstream watersheds at least at reconnaissance field survey intensity or by using data from more intensive studies, such as PL-566 plan development on 36 watersheds. Of the 99 remaining watersheds, 47 were estimated to be physically and economically feasible for upstream projects and 52 were not. Four of these were not feasible due to the effect of the ARMPP. The watershed investigation reports are included in Appendix 1, Volume II.

Surface drainage studies consisted of on-site observations and studies of river charts, lock and dam design memoranda, hydraulic profiles, topographic maps, aerial photographs, and drainage reports. The effects of ARMPP on surface drainage are set forth in reach reports included in Appendix 2, Volume III.

Methods for calculating water tables from piezometric pressures were devised using a mathematical approach. Various input factors of the relationships required reasonable estimates. These were based on the best data and judgment available.

Empirical methods were developed for predicting crop responses to fluctuating water tables. Reasonable estimates of plant respiration rate, growth rate, germination time, anaerobic survival time, etc., were evaluated to develop a crop response guide. This guide was used in conjunction with estimates of soil and environmental characteristics to predict the effects of specific changes in water table.

Of the estimated areas of crops and forests affected by water table changes resulting from ARMPP, 75% had benefits, 24% had no significant change, and 1% had damages. The estimated weighted yield increase of the major crops and forest was 28 percent. This involved assumed acreages of 4,300; 4,700; 48,200; 5,500; and 12,900 for small grain-soybeans (two-crop system), cotton, soybeans, alfalfa, and forest, respectively. The average weighted percentage yield increase was 35, 26, 29, 26, and 21 percent, respectively. Actual measured forested areas in 1969 were 13,482 acres. Increased yields resulted from beneficial use of water from the shallower water tables. Decreased yields resulted from delayed planting, lowered water tables, and encroachment of water tables into the root zones.

The observational study procedure was satisfactory to obtain the desired data. Briefly, some of the major findings were: alfalfa benefited from water tables between 2 and 12 feet deep but was killed by a short period of flooding; cotton and soybeans benefited from water tables five to six feet deep; soybeans were not damaged but benefited from a water table not deeper than one foot during the growing season; sorghum was damaged by a water table shallower than 2.3 feet; evapotranspiration lowered the water table as much as two feet below the piezometric surface; water tables and piezometric surfaces at elevations above river and pool stages were not influenced by them; water tables and piezometric surfaces were affected more by river and pool stages than by precipitation except in sandy soils with high intake rates; land use inventories were unsatisfactory for determining changes in cropping as a result of ARMPP; the piezometric surface can be as much as three feet higher than the water table;

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surface ponding of rainfall caused considerable damage to crops; supplemental irrigation would have benefited crops in all but one year of the seven years of observation; and soil moisture tensions at the three foot depth generally became high by the middle of the growing season.

Adjustments in land use to yield increasing and cost decreasing technology have not been considered in the economic impact study. Demand was not taken as a limitation of crop production. The value of production is expressed in terms of current normalized prices. All feasible projects were assumed in place in the analysis of the effect of upstream watershed development on production.

The installation of ARMPP resulted in reduction of cropland resource base by about 39,000 acres. The overall reduction in gross value of crops produced was approximately $953,000, which is less than one percent of the total value of crops produced in the ARMPP area. It is estimated that in the year 2000 the value of this lost production would amount to approximately $2,000,000.

The major adverse effect of land purchase was associated with Dardanelle and Robert S. Kerr locks and dams. About 70 percent of the land purchased in Arkansas and almost 85 percent of the land purchased in Oklahoma was associated with these two structures. The adverse effects of ARMPP were thus localized in Franklin, Johnson, Logan, Pope, and Yell Counties in Arkansas and Haskell County in Oklahoma.

Raised water tables resulting in increased yields occurred in Conway, Desha, Jefferson, Johnson, Lincoln, Lonoke, Pulaski, and Sebastian Counties in Arkansas, and Wagoner County in Oklahoma.

Production of corn, sorghum, and wheat decreased by more than four percent as a result of ARMPP. These crops are more commonly produced west of Little Rock, and in Oklahoma. Soybeans, cotton, and rice production was reduced by two percent or less. Most of the production of these crops occurs in the area south and east of Little Rock.

The installation of feasible upstream projects would have the most benefit in Arkansas, Jefferson, Lonoke, and Pulaski Counties. These benefits would come from the Bayou Meto, Plum Bayou, Ashley Bayou, and Pennington Bayou projects. Soybeans, cotton, and rice would be the crops most affected. In Oklahoma, the larger upstream projects would be Lower Bird Creek, Big Skin Bayou, and Dirty Creek. All crops produced in the Oklahoma portion of the study area would be increased as a result of the installation of upstream projects.

Under current cropping patterns in the year 2000, with and without ARMPP Project installed and ARMPP with upstream projects installed, the ARMPP area could produce its historical share of corn, sorghum, oats, hay, cotton, and rice, but not wheat and soybeans. Approximately 350,000 acres of cropland, currently either idle or in pasture, would be available for use. However, most of this is less productive land. As changes in demand occur, it is anticipated that changes in cropping patterns will occur.

The investigation of some related problems, such as possible increase in soil salinity, were not considered to be within the scope of this study.